GRADUATION REPORT

"Multi-use E-bikes for a post pandemic era."

FALKO DEN HERDER
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MASTER THESIS INTEGRATED PRODUCT DESIGN
INDUSTRIAL DESIGN ENGINEERING

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Master Thesis

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EXECUTIVE SUMMARY

The graduation project is commissioned by Bayck, a small E-bike start-up which focuses on designing affordable and simple e-bikes.
The company is looking for new market opportunities and perceives the Corona outbreak as a potential trigger for behaviour change towards mobility and e-bikes.

To find a relevant design direction for Bayck, information is gathered in four steps;
First, the pre-pandemic mobility is discussed, then how it is affected by the pandemic.
E-bike users are interviewed to understand the new use needs.
Finally, future visions from different perspectives are discussed to find a relevant context in which Bayck can design a new product.

From the analysis, it is concluded that the new Bayck product needs to be personal, enable multi-usage and invite the user to relax while going from A to B. The conclusions of the analysis are put together in a design brief.

An ideation is performed to come up with a design direction fitting the design brief.
To conclude the ideation phase, it is decided to design an e-bike that operates on a removable battery(-ies), also usable as a personal power-bank.

A storyboard is drawn to depict the ideal use situation.
The current Bayck model is taken apart to understand how an e-bike works and what should be integrated in the new design.

The concept is toned down to a level of feasibility: Two batteries of 18V are required to enable the user to charge its devices, but also use the 36V e-bike motor.

The challenge is made to simplify the e-bike as much as possible and separate the electronics as much as possible from the frame. The whole electronic system will be moved to the front of the bike to be as close as possible to the motor. This also enables the design to be mounted on the bike without modifying the frame.
The concept is taken from idea to materialized product through a fish trap process.
During the materialisation, a functional prototype is build to test the set up with two 18V batteries and the working of a new lock system.
The fish trap process results in a material concept, in which the different components and their assembly are established.

PROJECT INTRODUCTION

In the project introduction, the following is discussed: The client who commissioned this project, Bayck; The initial brief proposed by the client and its relevance to the context during which this project was performed; the research question that is set-up based on the brief of the client and finally, the proposed structure which is followed through the analysis of the Project. The analysis aims at answering the research question and building the new design brief on which the design phase of the project will be based upon.

THE CLIENT - BAYCK

Four of a kind

Bayck is a start-up that recently launched their first E-bike, founded in 2019.
The E-bike concept consists of a base frame, which can be equipped with different accessories to make 4 different models. Megacity, Athleisure, Commuter and Crossover.
The different models can be equipped with 2 different battery packs for more autonomy, a gear system of 3 or 7 gears and the colour of the plastic covers of the battery packs and chain-guards are customizable. The design does not include a display, the bike is controllable with an app on the user's smart-phone
The cheapest model is available at €1199.-, which categorises this E-bike as budget.
Their E-bike can be ordered online through their own interactive configurator. The E-bike is then delivered and mounted ready for use at the buyers location (Benelux only).
The company is currently in discussion with partners in Europe for the distribution of their product, such as Halfords or Decathlon BE.

Brand philosophy

Their concept aims at democratizing the E-bike, hence the slogan "a Bayck for everyone".
Their product is of high quality although meant to be humble without superfluous features.
Personalisation is a core aspect of the concept: the performance as well as the appearance of the bicycle are adaptable to the style and wishes of the rider.

It has all just Begun

The company envisions this E-bike to be the start of a longer roadmap. A roadmap consisting of multiple concept aiming at improving custom-fit mobility, connection between mobility modes and the affordability of mobility.
The company is currently in an exploratory phase, researching expansion possibilities in a broad way; the assignment given by the company is deliberately free.

This is the Crossover,
If you swap the front carrier with a rear carrier, it becomes the Commuter.
Without a front or rear carrier, it is the Athleisure.
If you remove the mudguards as well, it becomes the Megacity.
The covers of the plastic chain-guard and battery are currently available in 8 colours, but the company aims at adding new colours customization possibilities.

The battery is a central element to the concept. This quick-release battery is reverse compatible to become a gigantic power-bank. There is a USB-B slot in the bottom of the battery.

Components such as the lamps, mud-guards, wheels, tires, brakes, etc... are “off the shelf”. This means the concept is adapted to 3rd party manufactured parts, which limits the costs.

The down-tube of the frame is an aluminium extruded profile, in a hexagonal shape. This is rather unusual for a bicycle frame; it has the advantage of being light, structurally very strong due to the cavities on the inside of the tube as well as allowing cables to run through.

PROBLEM DEFINITION

Context

This project is initiated and performed in the middle of the world-wide Corona pandemic.
In the first stage of the pandemic, radical measures needed to be taken; offices, schools needed to close their doors entirely to hamper the contamination. Employees and students are asked to work from home and communicate digitally as much as they can.
The daily home-work commute for many suddenly disappeared.
With the coming and going of the number of contaminations, offices and businesses are scaling up and down the amount of people allowed on the work-floor but the situation is still uncertain and unstable.
Therefore, work is kept at home as much as possible and people are adapting. People are prepared if the situation is going to persist for a longer time.
Surprisingly, the distance working situation is experienced less dramatic than expected and even enjoyed by many. Less commuting means more spare-time; being confined at home means spending more time in family with less distraction from outside.
Even though people are confined at home, the indispensable displacements are needed be done, for groceries, bringing the kids to school and fresh air.
As car-lease contracts get cancelled, public transport are considered unsafe or confronting and all the displacements become short range, people start looking for alternatives.
The sale and use of E-bikes have exceeded numbers ever reached before.

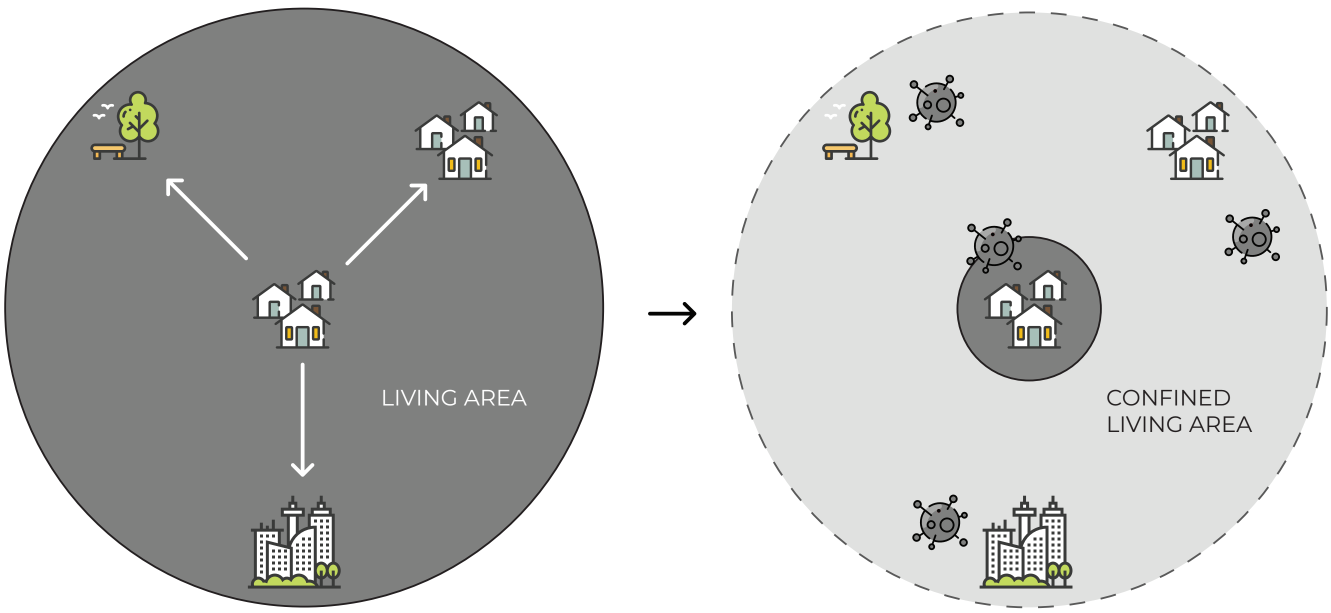
Assignment

The focus of this project is on the use of E-bikes within this new mobility context. Which daily basis needs are to be fulfilled within this new displacement range? What are the emerging needs due to this new situation?
The company identified that the E-bike became more popular for recreational reasons but stills needs to fulfil its practical functions. The company states that the use of an E-bike is very different between the Netherlands and the rest of Europe. Europe is identified as the potential market for the brand, as they want to expand their reach.
The assignment given by Bayck consists of identifying the changing multi-use needs of E-bike users and design a solution that fits these needs.

Personally, I think the current design of E-bikes is too unilateral: the E-bike is not entirely adapted to the needs of the user. With the extended possibilities of motorisation, the E-bike presents a canvas for new micro-mobility vehicles with new functionalities. Displacement or biking is more than simply moving from A to B, there are hidden qualities that I am willing to explore and integrate into an innovative concept.

Innovative concepts flourishing from the E-bike is not something completely new or caused by the Corona pandemic itself. The pandemic is rather emphasizing the importance of micro-mobility and boosts the mobility transition.

The official project brief can be found in the Appendix.



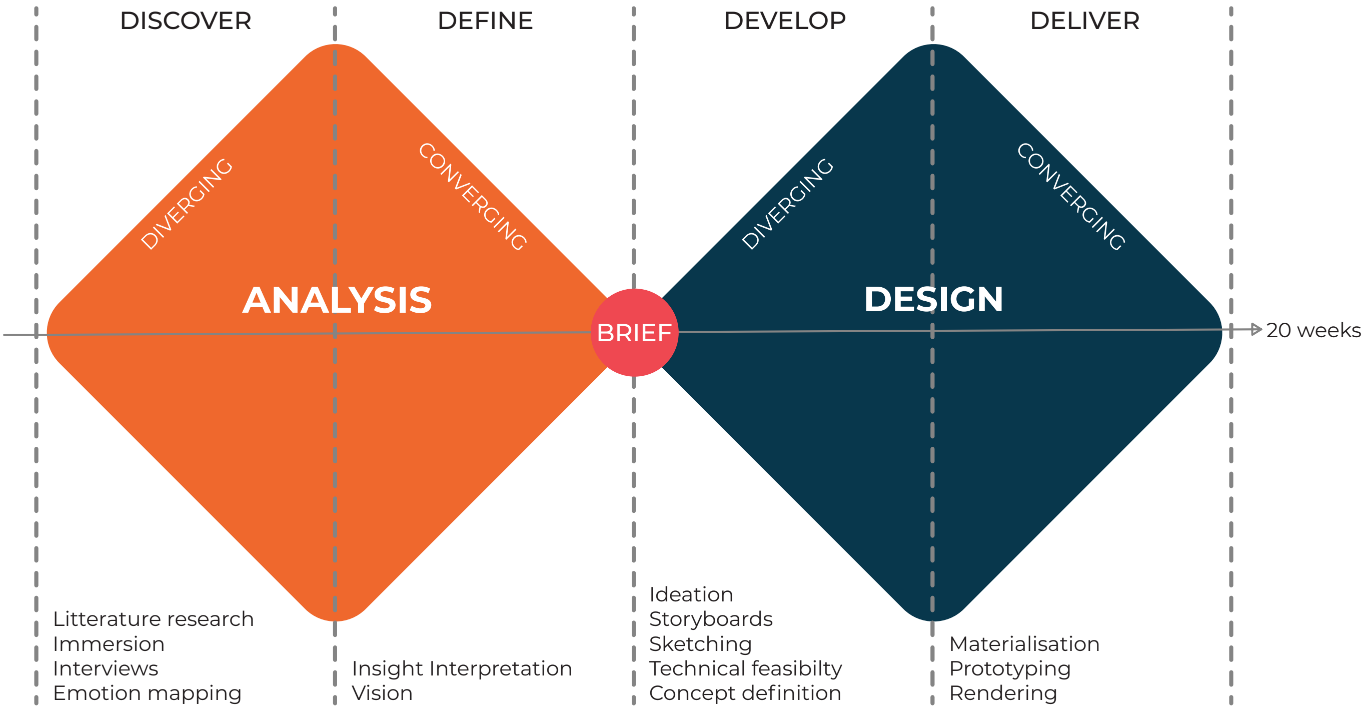
The living area is becoming smaller during the pandemic, how does it affect daily mobility?

RESEARCH QUESTION

How can Bayck design an E-bike related solution that fulfils the new use needs of European E-bike users triggered by the Corona pandemic?

DOUBLE DIAMOND STRUCTURE

The design project is separated into two phases: the analyse phase (Discover & Define) and the Design phase (Develop & Deliver). At the end of the first diamond, the research question is answered and a new design brief is set-up for the start of the second phase. The new brief together with a glimpse of the creation phase is presented at the mid-term evaluation. To study the pre-pandemic situation and the Corona inflicted situation change, literature study is done. To identify the new use needs, interviews are conducted. Most importantly, contrasting future mobility visions together with a personal vision are discussed at the end of the analysis; they are a key element to the shaping of the concept.



The project has a duration of 100 working days, from September 2020 to February 2021. The mid-term meeting takes place in November.
The final graduation date is May 17th 2021

-Analysis-

DISCOVER

PRE-PANDEMIC

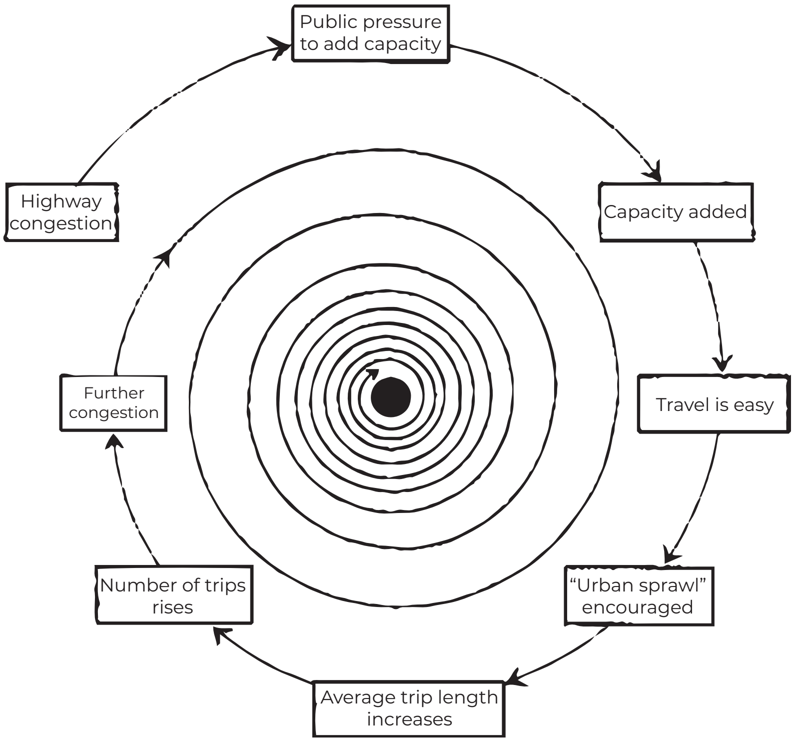
This chapter aims at collecting data on what the mobility situation looked like before the Corona pandemic in the Netherlands and in Europe. In the first part, information about mobility and the upcoming popularity are gathered. In the second part, biking behaviour differences between the Netherlands and other countries in Europe are discussed.

PRE-PANDEMIC MOBILITY

A majority of people tend to work in a different area or city than where they live: there were almost 4.5M commuters in the Netherlands in 2011, that is more than half of the professionally active Dutch (Meer Dan de Helft van de Werknemers Is Forens, n.d.). As the amount of commuters is rising over the years, infrastructure is modified and added to deal with the rising number of people in transit.
Surprisingly, the rising number of commuters is influenced by the debit of the infrastructure and not the other way around:
Even though the infrastructure is becoming more efficient and you can go faster from A to B than before, the average time spent on daily transit stays constant. This phenomenon is described in the Dutch BreVer law (Behoud van Reisteid en Verplaatsing): the average time spent on a daily basis for travelling remains the same (Peeters, 2001).

On average worldwide, people travel between 70 and 90 minutes a day (We Gaan Steeds Sneller, Maar Komen Geen Seconde Eerder Thuis (En Dat Is Een Groot Probleem) - De Correspondent, 2018). The travel distances have been augmenting along with the evolution of transport systems.
In that sense, increasing the speed of transit to desaturate the existing system is rather pointless, as the travelled distances will simply become bigger.

BRE-VER:
DAILY TRAVEL TIME IS CONSTANT,
DISTANCE IS VARIABLE.



Plane, D. A. (1995)

“Also without a purpose, we want to be mobile. [...] We must, I’m afraid, stop whining and accept that there are traffic jams.”

Carlo de Weijer
Director Smart Mobility, TU Eindhoven.

A positive development in counter movement to saturation of infrastructure is micro-mobility. Smaller, electric vehicles are replacing larger vehicles within cities. Micro-mobility favours shorter displacements, goal specific.
A manifestation of micro-mobility is the rising popularity of E-bikes: 15M units sold worldwide in 2015; “most rapid uptake of alternative fuelled vehicles” (Sun et al., 2020). Micro-mobility as a viable solution for desaturation of urban areas.

In the Netherlands, 25% percent of all the displacements are done by bike, this number has been rising over the last years. Biking is becoming more popular amongst younger groups (<65y) partially due to the popularity rise of E-bikes (Harms & Kansen, 2017). In contrary to what men might think, the most of the bike use is for recreational use.

Takeaways:

Daily travel time of people is on average constant, we travel even without a purpose.
Faster transport modes is permitting to travel greater distances, not travelling less time.
E-bikes are part of a micro-mobility development that is perceived as a solution for mobility cluttering.
The E-bike is gaining popularity, also amongst younger generation and is mostly used for recreational purposes.

BIKING BEHAVIOUR IN EUROPEAN CITIES

The client expressed the willingness to target the European market with their products. As bike use in the Netherlands is quite unique compared to other countries, cycling related information is gathered from European cities where biking is popular. This information is relevant for the design phase, to make sure the design fits a European context, and is not biased by the Dutch market.

Copenhagen:
The average budget spent on bikes is higher, higher quality bikes. Bike use similar to Netherlands although more variety in models, functionalities.

Paris:
large variety of bikes, emerging biking culture coming together with better biking lanes. Cyclists are better equipped (helmets clothes), biking something new and special. Aid from government to get your bike fixed during pandemic. Structural change of the city to stimulate biking.

Berlin:
More protection, well equipped, functional and comfortable bikes. Infrastructure is not adapted for biking and quite dangerous, biking in Berlin is an adventure.

Bordeaux:
Similar as in Paris or Lyon, Bordeaux is one of the French cities with an excellent bike sharing system, with retrieval and drop off stations dispersed over the city. Soft weather the year round, biking became fairly normal.

Geneva:
Qualitative equipment. you can get fined for cycling without a helmet. Cycling is an alternative life-style. Because of the height differences in the city, sportive bikes and adequate clothing, sporty people.

Amsterdam:
Biking is a commodity; although biking infrastructure has been around for a long time, the new development is slacking and the number of cyclists is outgrowing the city. Most of cyclists own dull bikes to make them less appealing for theft. Lots of people cycle on partially broken bikes, as long as it keeps rolling. On the other hand, the use of bikes is omnipresent: from taking the kids to school to package delivery.

Takeaways:

The overall difference between the Netherlands and other countries in Europe:
cyclist in other countries seem to be more conscious about the bike there are owning and using, or the fact that they cycle, period. People own clothes and accessories specifically for their biking activities. Having proper equipment, a helmet or lights is common, who wears helmets in the Netherlands? Being a cyclist in the other mentioned cities means belonging to a group that is not a majority (Copenhagen is an exception). The recreational aspect of biking is more dominant in other countries.
Can the commute change due to pandemic in Holland can make us more conscious about our bike usage?

SITUATION CHANGE

In this chapter, the commute changes due the Corona virus are discussed. The virus obliged people to work from home, negative but also positives effects are observed. At least, the virus is beneficial for the popularity rise of the E-bike as discussed below.

COMMUTE CHANGE DUE TO CORONA

During the lock-down in Holland, most of businesses were closed. Half of professionally active Dutch people were able to work from home.
Companies and employees expressed overall positivity towards home-working, A part of these people expressed concerns on the long run about their private/work balance (36%) and their physical or psychological state (10%). (The Netherlands Institute for Transport Policy Analysis (KiM), 2020).
A downside for office attending commuters which are now working from home is that their car lease or train subscription got withdrawn for many, which reduced their mobilty even more (Ambtenaren Mogen Blijven Thuiswerken | Computable.Nl, n.d.).

The Corona pandemic and the disappearance of home-work commute put an emphasize on the benefits of commuting on personal lives. Commuting time is used for a "role shift": the way we act in our private lives as a flatmate, spouse or parent is expected to different than at work. The time spent between roles is a time used for mental planning and preparation or reflection at the end of the day. These moments favour a so-called gear change. When the different roles blend into each other, we face a psychological challenge that researchers call "role ambiguity". (The Neglected Benefits of the Commute - BBC Worklife, 2018.)

Local co-working offices are perceived as a solution to the concerns mentioned above; these recently developing co-working places offer qualitative and ergonomic office equipment as well as the possibility to maintain physical social interactions (Why Coronavirus Isn't the End of Coworking Spaces. | B. Building Business, n.d.).

The amount and use of (e-)bike has remained in a stable rise during the lockdown in the Netherlands, although it is identified that former car and public transport users will continue to shift to the use of bikes with the diminishing of their mandatory displacements (The Netherlands Institute for Transport Policy Analysis (KiM), 2020).
Since the beginning of the crisis, the overall amount of displacements diminished drastically; the displacement for "touring and strolling" (recreation in other words) have on the contrary risen. (The Netherlands Institute for Transport Policy Analysis (KiM), 2020).

Takeaways:

The hampered commutes due to the pandemic had a less dramatic effect on work productivity than expected. The attitude towards distance working is mostly positive, There are nevertheless concerns about social interaction and physical health. Commuting permits psychological processes that are beneficial for separation of professional and personal lives; the time is required for a role shift.
The rise of (e-)bike use and purchase kept stable during lockdown, although the use combined functional with recreational more.

NEW USE NEEDS

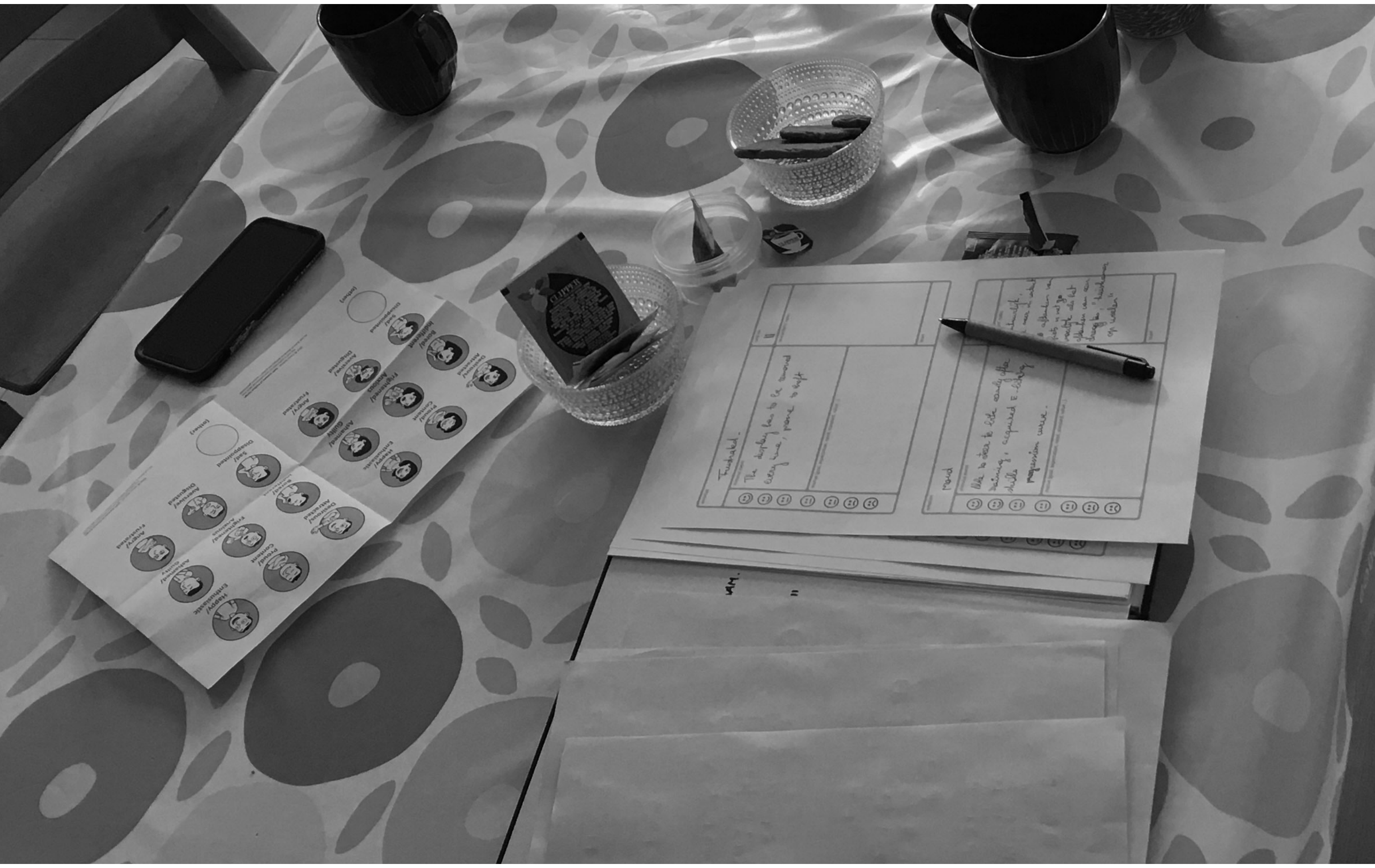
**The new use needs are researched in a qualitative way. Emotion capture (EC) plus interview/ discussion with e-bike user with altered home-work commute.
The aim of the interview and EC is to find patterns in user needs regarding E-bike use and reveal interesting and noteworthy needs.**

EMOTION CAPTURE

Emotion capture is Design for Interaction Method. It is a observation/interview technique that aims discussing the emotions a user feels when using a product or service.
Emotions hide personal motives. They are a manifestation of a fundamental needs. Most people find it hard to express the underlying needs in a standard interview or survey. Answers may be biased or simply superficial.
This method aims at capturing emotions during the use of a product, in our case an e-bike. The emotions are captured on so called emotion capture cards. The name of the emotion, their intensity and what triggered them are written down during the use.

Post to the capture, a reflective interview is conducted to discuss every captured emotion. The aim of the interview is to dig deeper, discover the underlying motive and need that was fulfilled or not and find out how it was triggered. The fundamental needs of humans are mostly the same, such as belonging, security, autonomy... People fulfil these fundamental needs differently, and express different emotions when they are triggered.
Laddering from emotion down towards the fundamental need in multiple steps helps understand behaviour.
Two persons are interviewed using this method.

The filled capture cards can be found in the Appendix.



Anna Bootsma

Anna is young mother living in Zeist with her partner and her 3 young kids. She is working for Infram located in Utrecht. .She is working from home since the beginning of the pandemic.
The E-bike she is using an Urban Arrow Family cargo bike.
She owns a SUV which she used to drop off the kids at school, go to work in Utrecht and collect them at the end of the day. She already owned the cargo-bike before the lock-down.
The primary use of the car switched to the Cargo bike. She is able to bring the three kids to kindergarten/school at once since she mounted an additional seat on the rear carrier.

Bike Use

The bike was mostly used on weekends for recreational use, going into nature with the bike and the kids.
Now, the bike is used for recreation, but daily necessity as well. The distance to the shop, school or kindergarten is quite small, therefore the car is excessive.

Example positive emotion, stimulus event and underlying motive

Pride
When taking the kids out into nature on weekends, the behaviour of the kids is completely different between being at the back of the car or being on the bike. They are more attentive to what happens around them. She feels more connected to them, because she able to see them, talk to them and focus on them more without bringing them in danger (she is cycling at a reasonable speed on a separated bicycle lane). She enjoys spending quality time with them in nature, and allow them to be more in conscious about their environment.

Example negative emotion, stimulus event and underlying motive

Frustration
The display can be taken off easily even when the bike is locked. She has to take the display with her in the pocket of her jacket, she is afraid it will get stolen. They display is required to use the bike correctly and needs to be charged often as well.
She dislikes being anxious about removable parts on her bike and being dependent on the display. She wants to focus on what matters to her during cycling, meaning having a memorable moment with her kids.

Additional information, interesting statements

Anna compares the bike to a child carrier backpack: She takes her kids on expedition on weekends, on day trips. Her partner enjoys taking videos and pictures of the kids enjoying the ride. Therefore, the bike is present on many child pictures hanging around the house. She associates the bike with pleasant memories of sunny weekends and fun.
She appreciates the pedal support of the bike when the bike is fully loaded, it helps her keeping the balance while cycling at low speed.

Karin Schoonhoven

Karin lives together with her partner in Maarsbergen. She works for Inspectie Leefomgeving en Transport (ILT) in Utrecht, she used to commute every day back and forth. Karin recently moved from Amsterdam to this greener area of the Netherlands, to enjoy the pleasures of nature and a more spacious house. Her partner bought two second-hand, identical e-bikes on Marktplaats for both of them. The former owners engraved their names in the frame and on the battery.
Before the pandemic, she rarely used the E-bike since she was mostly using her car to go to work or other appointments; she gradually started to use it more often the more she was required to work from home. The e-bike she owns is a Batavus Intermezzo Easy.

Bike use

She sometimes uses her e-bike to go to the centre of town, to do her groceries; but with the pandemic situation, she avoids going to the shops too often. Meaning that when she goes shopping, the amount of stuff she buys is mostly too much to carry on her bike. Therefore, she prefers to use the car instead, even if the shops are not far away. She mainly uses the bike for recreational purposes; she mostly uses it at the end of a long home-working day to enjoy some fresh air. Karin nearly almost combines her trip with a useful activity (shops, family visit) to make the trip look less pointless. She mostly uses the pedal assistance on a low amount, she enjoys doing a physical effort, use cycling as a way to exercise. She mostly uses pedal assistance when she is heavily loaded or when she needs to go further away from home.

Example positive emotion, underlying motive

Happiness
when cycling off after being inside for a whole day of work. The pedal assistance is set very low so the bike is giving some resistance. It allows her to stretch her legs and exercise a little. Karin compares it to a stroll on foot; although the bike allows her to go further, to different places instead of walking around her own neighbourhood.

Example negative emotion, underlying motive

Reluctance
the display has been broken for a long time but she did not take the time to fix it yet. It is now hanging on poorly to a tie wrap. The display should indicate the level of the battery, but it does not seem to work, or she does not know how it works. The information is redundant anyway because she can check the charge level on the battery itself. When the battery is fully charged, she can use the bike multiple times before it is drained. She checks the level of the battery before leaving but does not see the purpose of having a second display on the steering. It is a fragile component and it eventually broke when it was parked. She would rather take it off completely but it is complexly wired and it would take her some time to manage that.

Additional information, interesting statements

Independence: she wants to be able to operate the bike herself, but until now, her partner was taking care of the maintenance, the charging of the battery and knew the location of the tools required to adjust the saddle. He was away for a week; she did not know the ins and outs of her own bike.
Karin wanted to adjust the saddle but could not, she was unable to find the right tools. Because she was cycling with the saddle too high, the ride was quite uncomfortable. She finds it ridiculous that you can adjust the steering height with a quick release, but not the saddle.
Frustration, when she has some stuff in her carrying bags, she cannot leave the bike unattended, she is afraid the containments will get stolen.
She felt aversive to the bike. It is ugly and clearly targeting seniors. Even though it was practical, her pleasure of biking was diminished by the way it looked and what it makes her look like: a housewife running her errands instead of a recreational cyclist.
14 emotions were captured during the interview, 11 of them are negative; The positive emotions were not triggered directly by the bike itself but rather by enjoying being outside/ the weather. Although the grand majority of negative emotions were triggered by specific features of the bike itself.

INTERVIEW

Interview with Michael Mischke

Michael is interviewed for this project for two reasons; on the one hand, he experienced a change in his home to work commute situation and on the other hand, he has been involved in mobility projects and has a sharpened vision on Mobility. His own situation as well as the cycling situation in Berlin is Discussed.

Michael

Background in UX ergonomics in usability, service design, mechanical engineering.
10 years in automotive Audi, Volkswagen
Self-employment consultant, including service design for mobility for cities. Proposing bike lanes and mobility hubs to connect owned bikes with shared bikes.
Current job: Old world/new world digitalization transition for NGO's.
Father of 2 kids, living with his wife and kids on the fourth story of a flat in the south of Berlin.
Owner of multiple bikes, including electrified cargo-bike.

Commute habits before pandemic

Used a bike 95% percent of the time, sometimes in combination with S-Bahn to reduce travel time. Swapping turns taking the kids to kindergarten by cargo bike with his wife.
His consultancy job took all around the city, biking to get around town. Sometimes using public transportation when he needs to get somewhere further or faster.
For own company: a rented office in the centre of the city.
Using a shared car on weekends to escape the city and take the kids into nature. Because of their young age, they need to nap often, car is more convenient than public transports.

Commute habits during pandemic

More biking, less public transports. Working 100% from home, takes the kids to kindergarten with the cargo bike daily nonetheless.
He discarded the office he was renting because it not possible to join the office anymore.

Bike related initiatives and developments in Berlin

Less "single meal shopping" to limit the number of supermarket visits. People try to go shopping once a week instead. He saw that people used cargo bikes or car sharing to get all the groceries home due to a lack of loading capacity on regular bikes.
Such as in every major city in Europe, shared mobility systems are appearing and crowding the streets; Swobbee is an example of a start-up which is implementing public battery changing stations on the streets of Berlin; for a monthly subscription, you can extract a charged battery for the station and use it on your bike.
The critical parts of your bike are not your possessions. Flotte Lotte is an example of shared

cargo-bikes, available for a monthly subscription, users can use the bikes that are always parked on a fixed location. The concept is as low-tech as possible: the bikes are locked with a regular combination-lock, every bike has a head renter which is responsible for taking it to maintenance, checking if it is still in good condition and parked correctly. The community spirit and mutual trust within this service is an incentive for people to be more careful with the bikes even though it is not their property.

Michael on Mobility as a Service

at the point it is now, it doesn't fulfil the daily need at all. We are creatures of habit; it is odd that we would have to check the mobility possibilities every morning. Family life especially, is made out of rituals. Kids need these rituals for their orientation.
On the other side, MaaS give the possibility to test out new forms of mobility, bring alternative ways of transportation into people's lives.
For example, no-one in Berlin would consider an e-car because there are no charging stations; Even though the city is just too full to drive around, electric car-sharing are introduced; it is not possible that these services are economically viable. But Berliners enjoy driving in a carbon neutral way, especially on weekends to get out of the city or shopping. MaaS E-mobility is therefore maybe a way to speed up the transition because it makes it easy to try out new mobility modes.

Education

Every now and then, Michael has to take his bike to the gas station to use the vacuum cleaner and clean the box of his cargo bike. The box needs to be varnished sometime as well to remain in good condition. These are activities he enjoys doing together with his kids, to teach them how to take care of their things.
on the other hand, you see E-scooters being trashed around the city. They are attractive and exciting for the kids; they are longing to try them out. But they also see how they are trashed and vandalized: technology is presented as disposable.
They are used a few times and then disposed. It has a terrible impact on the economy but also on the careless behaviour of society.

Takeaways:

The e-bike was primarily used functionally or recreationally, the new use situation is combining both more.
Being together on a bike creates a connective space, for discussion, exchange.
Being on a bike has a relaxing effect on kids/ users (expect for people from Amsterdam, they are a lost cause).
Cycling makes you more aware of your direct environment, compared to a car for example.
Cycling helps thinking, reflecting. -> probably displacement, not cycling specific. (Jos in the car back home shuts down a day at work).
The amount on convenience of loading space weighs high on the appreciation of the e-bike.
"Specs" (battery capacity, motor performance, weight...) had little impact on the appreciation of the e-bike.
One repeated major advantage of a bike compared to car is being outside, bad weather not real problem (Berlin different than Netherlands).
Gadgets, electronic displays and wiring are mostly identified as superfluous, annoying
A bike can become a family object, that they use and maintain together (more accessible that the complexity of the car?).
An aesthetic aversion to the bike, a dissociation with personal image and preference hampers the experience of biking.
The understanding of the bike, it's simplicity in use and maintenance contributes to appreciation of the Bike.
Mobility services are a good way to easily try out new mobility modes, or practical for occasional events.
MaaS is not desired for day to day routine.

-Analysis-

DEFINE

VISION

What are the mobility plans for the future, and who makes them?
The bold and revolutionary plans for the future elaborated by major players in the world of mobility are exposed. The technological progress does not come without a price: experts express their concerns about the hidden impact of progress. Finally, a personal vision and motivation about the project is presented.

FUTURE OF MOBILITY

Commuting habit change

It is forecast that distance working will gain of acceptance from this point on; The acceptance of virtual meetings in the Netherlands already doubled since the beginning of the pandemic. 60% of the respondents of the survey expressed they will be meeting virtually more often even after the pandemic measures are withdrawn (The Netherlands Institute for Transport Policy Analysis (KiM), 2020).

Technology driven future

If we believe future mobility plans elaborated by 25 mobility companies in the Netherlands, the future of mobility is technology driven. The proposed solutions to desaturate infrastructures and reduce carbon footprint is to build more infrastructure, reduce ownership and enable vehicle to vehicle communication. HUB's in cities and rural areas to concentrate multiple mobility services in order to enhance the connection between transport modes. A shift from payment for possession to payment for use, breaking up habit commute to daily altered commute to spread the passenger load over multiple transport modes. They present a utopian vision of the future in which typical users are seamlessly brought from A to B completely assisted by their phones and autonomous vehicles. This plan is aiming at reducing congestion on infrastructure, reducing carbon footprint by efficiency, improving connection between urban and rural areas as well as making mobility accessible for all (Mobiliteitsalliantie, 2019).
This vision is also visible overseas. Former CEO of Ford Motor Company Bill Ford presents the vision of the company: Role of real-time data and autonomous systems, mobility is a freedom, increasing travel distances will become bigger, Global Grid-lock 2050 is biggest threat to economy (Bill Ford: A Future beyond Traffic Gridlock | TED Talk, n.d.). The recent successful test of a Hyper-loop built by Virgin with passengers aboard triggers excitement all over the world.

Flip side of the coin

The impact of the technology driven progress is overshadowed by the promised benefits for the user. A common term for scientists describing the impact of omnipresent interconnected devices is the “IoT flood”.
The use of real time data requires the use of a fast internet connection, 5G. This connection between all kinds of devices (cars, traffic lights, phones, etc...) requires an enormous amount of energy plus an enormous amount of electronics and rare materials in order to operate (Xu & McArdle, 2018).
Rare materials that are required for production of these systems are increasingly becoming rare, hard to mine, and therefore expensive (Bihouix, 2014).
The global scale mining race has started to ensure the supply of materials of the future (De Vuile Strijd Om de Metalen van de Toekomst, 2020).
MaaS is described as the ultimate solution for all mobility problems, but as Carlo de Weijer says: People are “Maas-tired”, since existing services are not economically viable (Micro Mobility Revolution: Startups, Companies & Market Solutions l CB Insights, n.d.), polluting the streets and not durable because the society is not ready (Interview | Carlo van de Weijer: We Worden MaaS-Moe - De Mobiliteit Voor Morgen, n.d.).

PERSONAL VISION

Being completely dependent on technology for daily needs is not a freedom but a restriction. Technology should be an aid, not taking over our capability to think for ourselves, succeed and fail. We should be more aware about the technology we are implementing and using: what is really augmenting someone's quality of life and what is superfluous nonsense used for market differentiation?
Do we really all need a 4K cameras in our phones to take selfies with AR bunny ears (Iphone) ? What is the use of thermostat with an OLED touchscreen (GLASS) ? Why should be able to play piano on the touch-screen dashboard of a car (Tesla) ?
High-tech product with loads of features are

prone to become obsolete faster.
Disposable technology as a result of this technology race is a plague; technological superiority is used as a marketing tool although it does not fulfil a human need, only short-term desires.
The real challenge for designers, is to implement products that focus on these long-lasting needs, with superior quality over time (reduce obsolescence), adapted to the user's preferences, and attractive budget wise.

Humans are creatures of habits; a routine is important for mental stability. We are losing connection with our environment;
Mobility has a major impact on the environment, we should focus on reducing travel distances instead of allowing longer commutes.
My ambition is to design durable and qualitative products, to offer an alternative for people that are not willing to be dominated by technology in their daily lives.

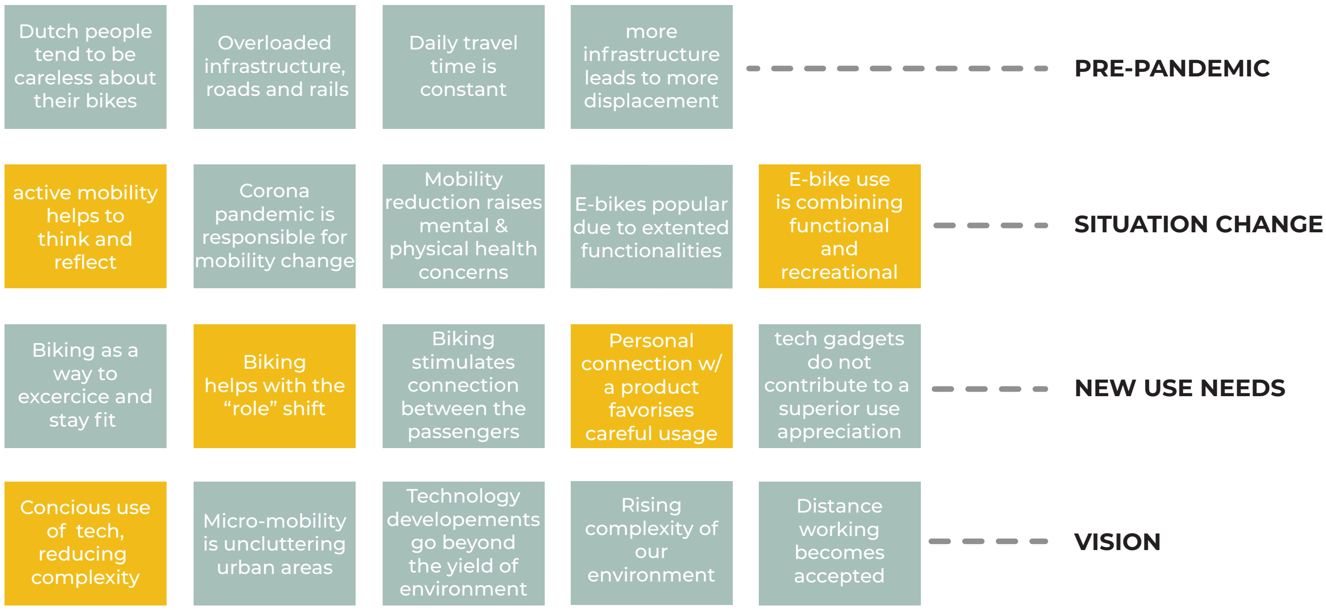
Takeaways

Distance working will become more and more accepted over time.
Fluent mass mobility is perceived as a priority for mobility companies and governments. Plans are made to multiply the amount of infrastructure. If we look back at the conclusions of *pre-pandemic situation*, we can understand that this does not really make sense: more transport systems and infrastructure leads to more displacements.
Mobility systems but also our world in general are becoming more complex, introducing smart systems, services and electronics everywhere.
A massive amount of developments in data exchange, electronics are required to ensure this infrastructure development, which cannot be done in a sustainable way.
MaaS is sacralized as the saving solution for all mobility issues. It rather introduces interesting applications such as occasional use but should not be exaggerated.
It might be compared to the hype around 3D printing in the industry.

Uber Jump bikes, disposed within a year after implementation.

INSIGHT MAP

The takeaways extracted from literature research and interviews are gathered in an insight map. The map is build to understand how the insights relate to each other. The outcome of the insight map is the foundation of the new brief.
The differentiation is made between facts extracted from literature research with trends and opinions mostly extracted from the interviews or informal literature such as news articles. Some insights are envisioned as threats or limitations for societal development and others as opportunities for this design project.

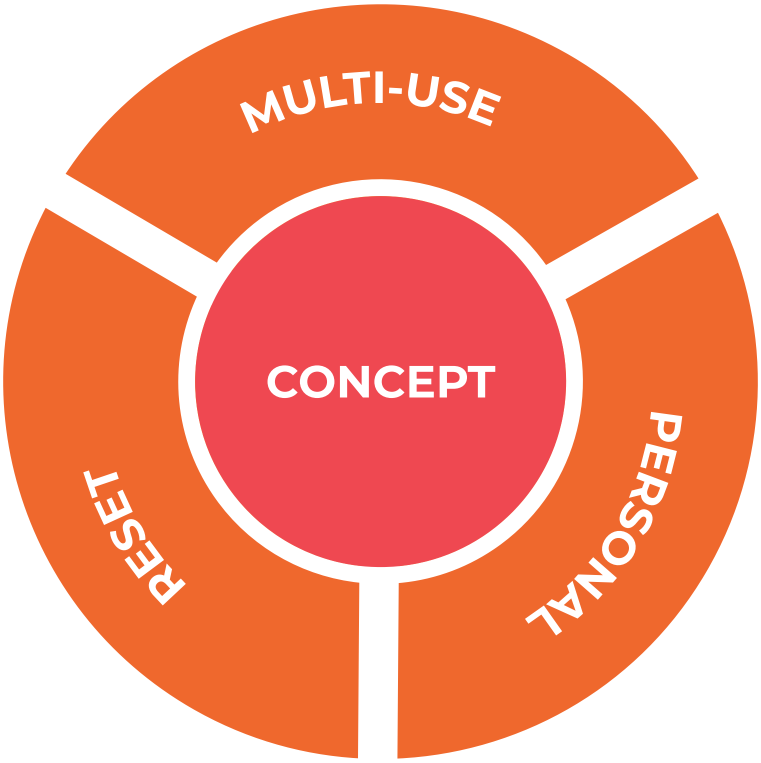


Fundamental needs of people are taken as foundation of the graph. Why? The focus of the project is human driven instead of tech or problem driven.
Three main elements are pinned as opportunities for the design brief.
1: E-biking is combining recreation and functional use better.
2: Biking has positive influences on the mind and body of the user. In the context of this project, biking can help make the transition between different modes: e.g. from employer to dad.
3: A personal connection with the product one uses favours the user taking care of the product and use it for a longer time.

The new design brief is constructed based on these three pillars.

NEW BRIEF

The new design brief is constructed based on the three opportunities identified in the insight map. The three elements of the new brief being *Reset*, *Multi-use* and *Personal* are the starting point for the conceptualisation phase.



Personal:

The functions of the concept are personalised to the user needs. The aesthetics of the concept are adaptable to the preferences of the user.
The concept presents wear and tear over time, showing the use of the owner.

Reset:

The concept helps in transition from one role to another in daily life.
The concept helps the disconnection from the digital world.
Physical exercise is facilitated.
The concept stimulates connection between multiple simultaneous users.

Combined use:

The concept can be used for recreational purposes as well as functional purposes.

The answer to the research question:

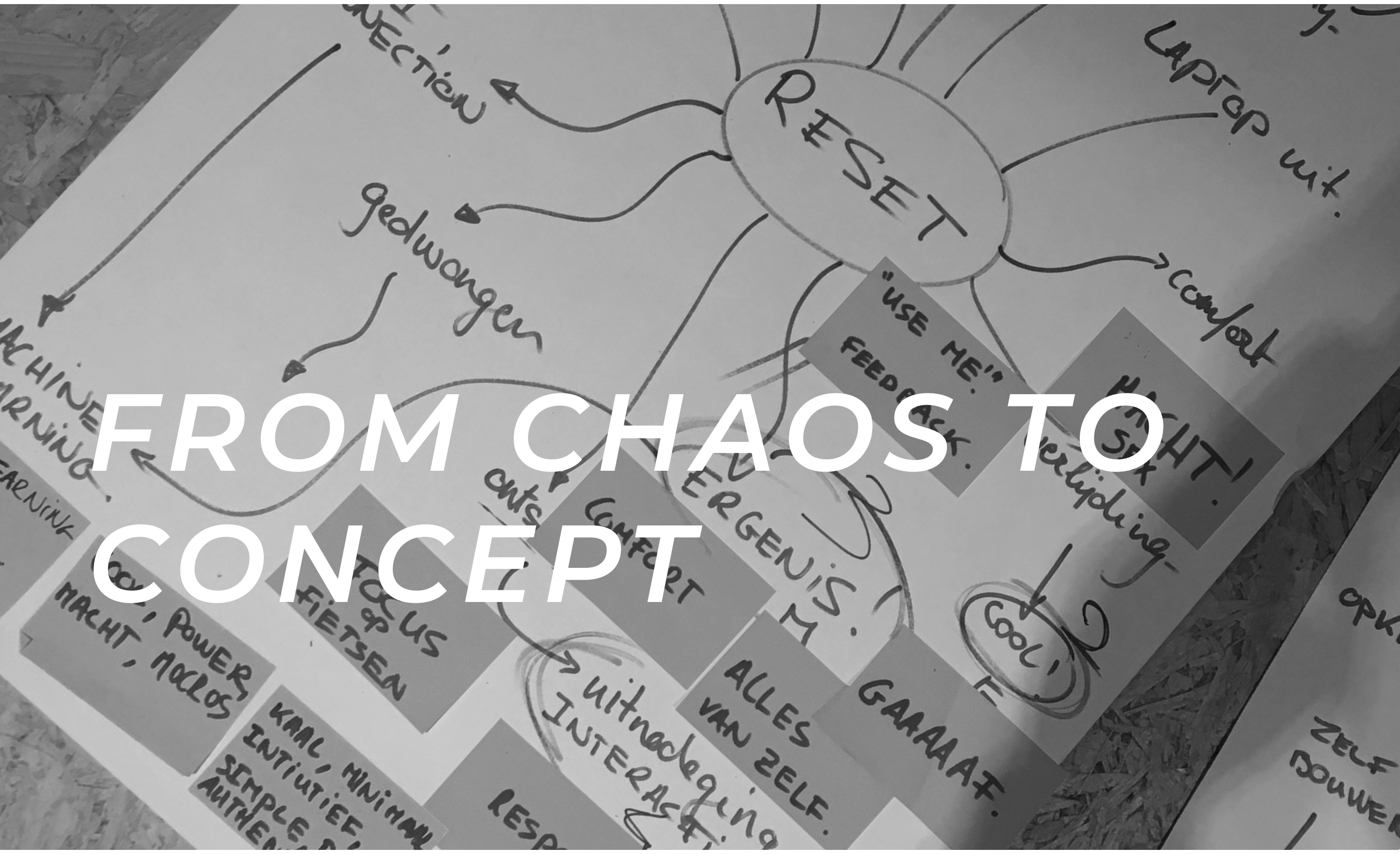
“Design a concept which allows multi-usage, fitting the personal preferences and enabling a “reset”of the user.”

-Design-

DEVELOP

IDEATION

The goal of the ideation is to come up with a concrete design direction for the ongoing of the design development. As the three design pillars pinned in the design brief mean different things for different people, A mind-map is made, together with the Bayck team, but also with non-designers to gather as much definitions as possible.



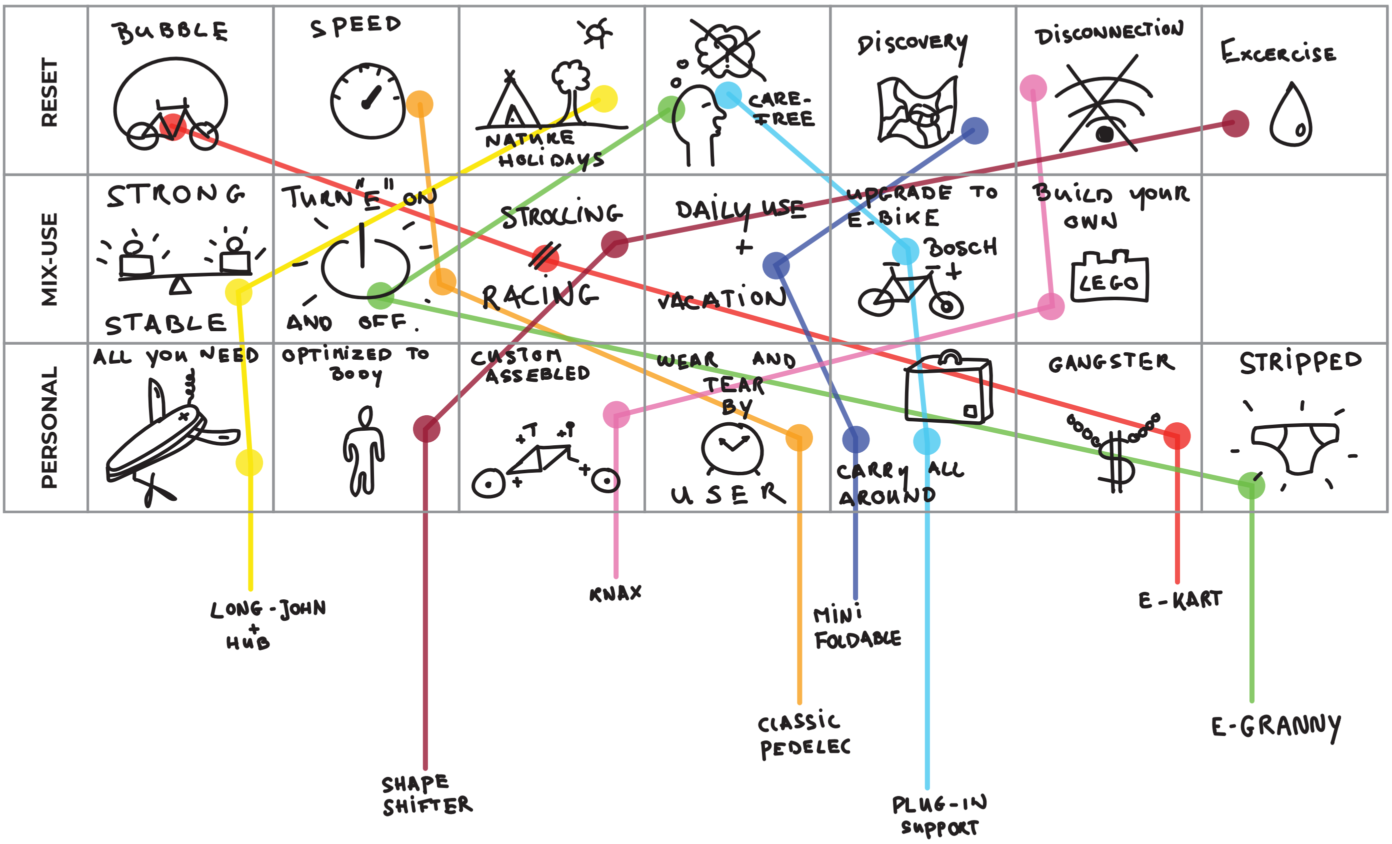
FROM CHAOS TO CONCEPT

MIND MAPPING

The ideation is divided into multiple activities. The first activity is mind-mapping; mind maps are made with RESET, PERSONAL and MULTI-USE as theme. This activity is done multiple times with different participants, as well internally with the company team as with external designers in separate sessions.
The mind maps aim at exploring the meaning of these words and how this is achieved or manifested within other products.
As a result, the mind maps presented several interesting factors, some concrete with product examples or analogies, some more abstract.

To prepare the second step, the company team selected factors based on their or preferences and they are put into a table. Three rows for the three mind map topics and the mind-map factors into the columns.

IDEATION DRAWING

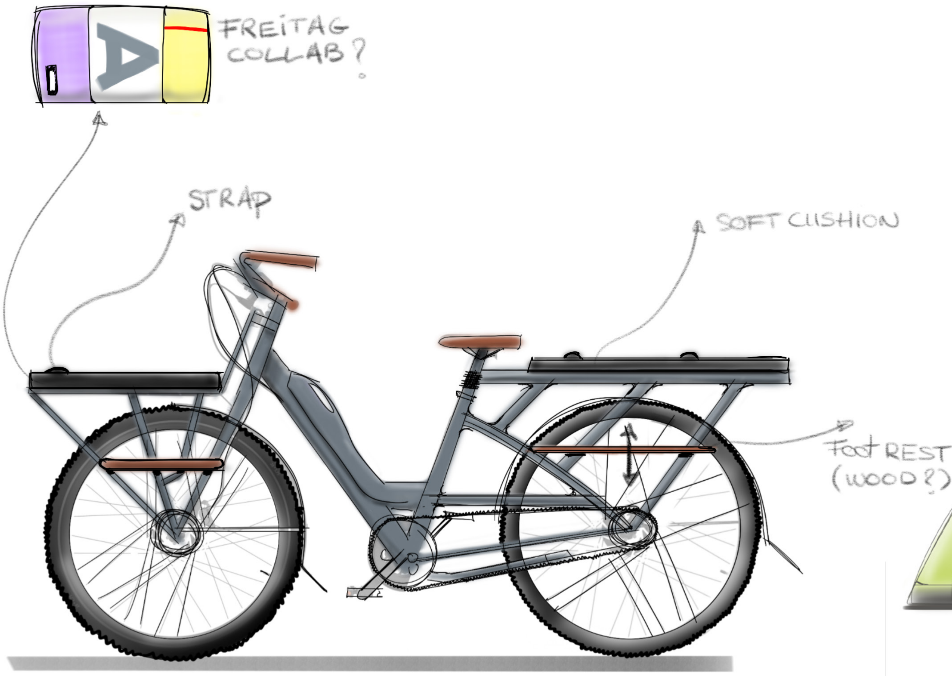


CONCEPT TABLE

Teams of two are made; each team is asked to select one factor of each topic, and draw a concept merging the three factors; the teams are required to prepare a small presentation of their concept. This step was repeated several times to cover all the factors and create a large series of rough concepts.
At the end of this phase, the teams vote for the most outstanding rough concepts, the vote comes down to a pre-selection of 8.

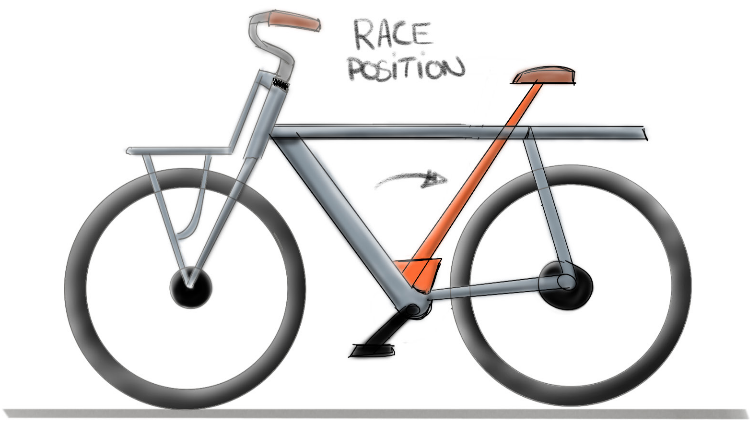
Follow the coloured lines to see which factors are used to form each rough concept.

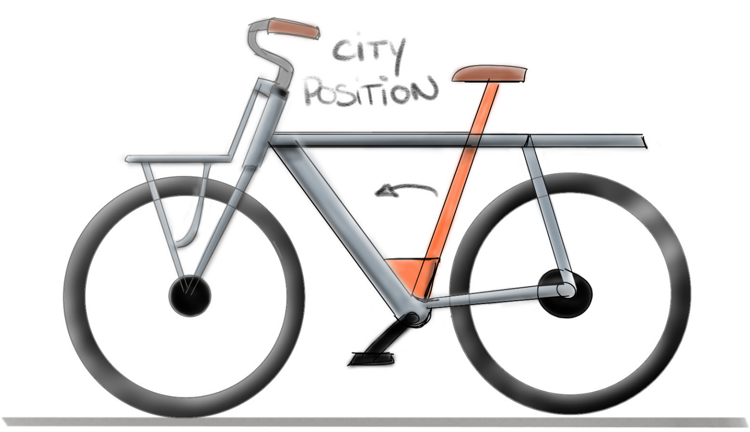
LONG-JOHN + HUB



The Long-John + Hub is based on the current Bayck frame with an extended drive train. A connection hub is placed on the front and back of the bike allowing different modules to be attached to the bike.
The concept promises a long design trajectory, with development of new add-ons over time. This concept could be a more affordable alternative to high-end E-bikes brands such as Rieser&Müller.

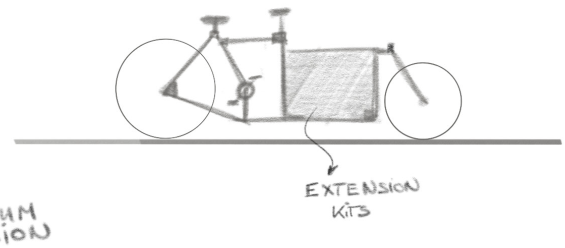
SHAPE SHIFTER

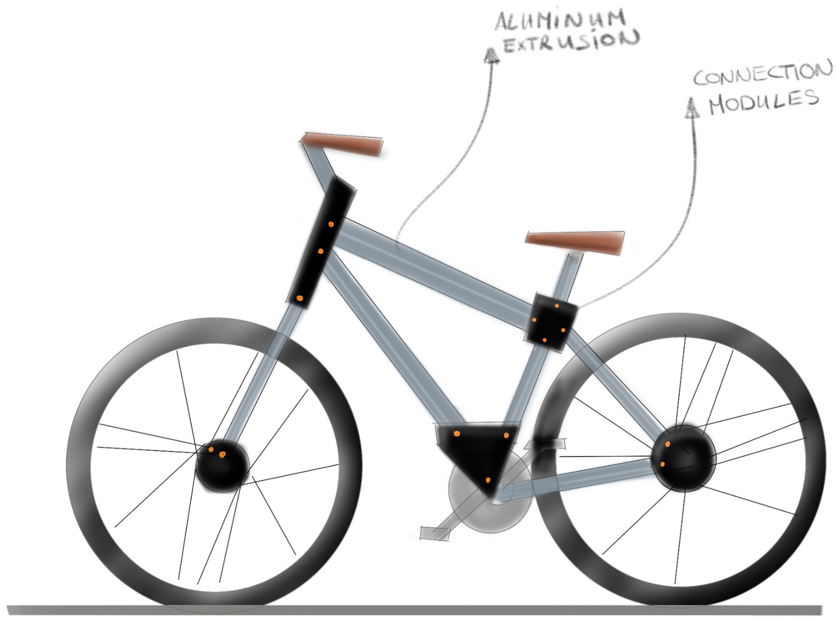




The Shape Shifter is morphing between a city bike and a sporty bike. The position of the saddle adjusts to the mood of the user. The concept presents a single bike for multiple purposes and a degree of novelty. The company foresees a complex and high-tech design solution.

KNAX





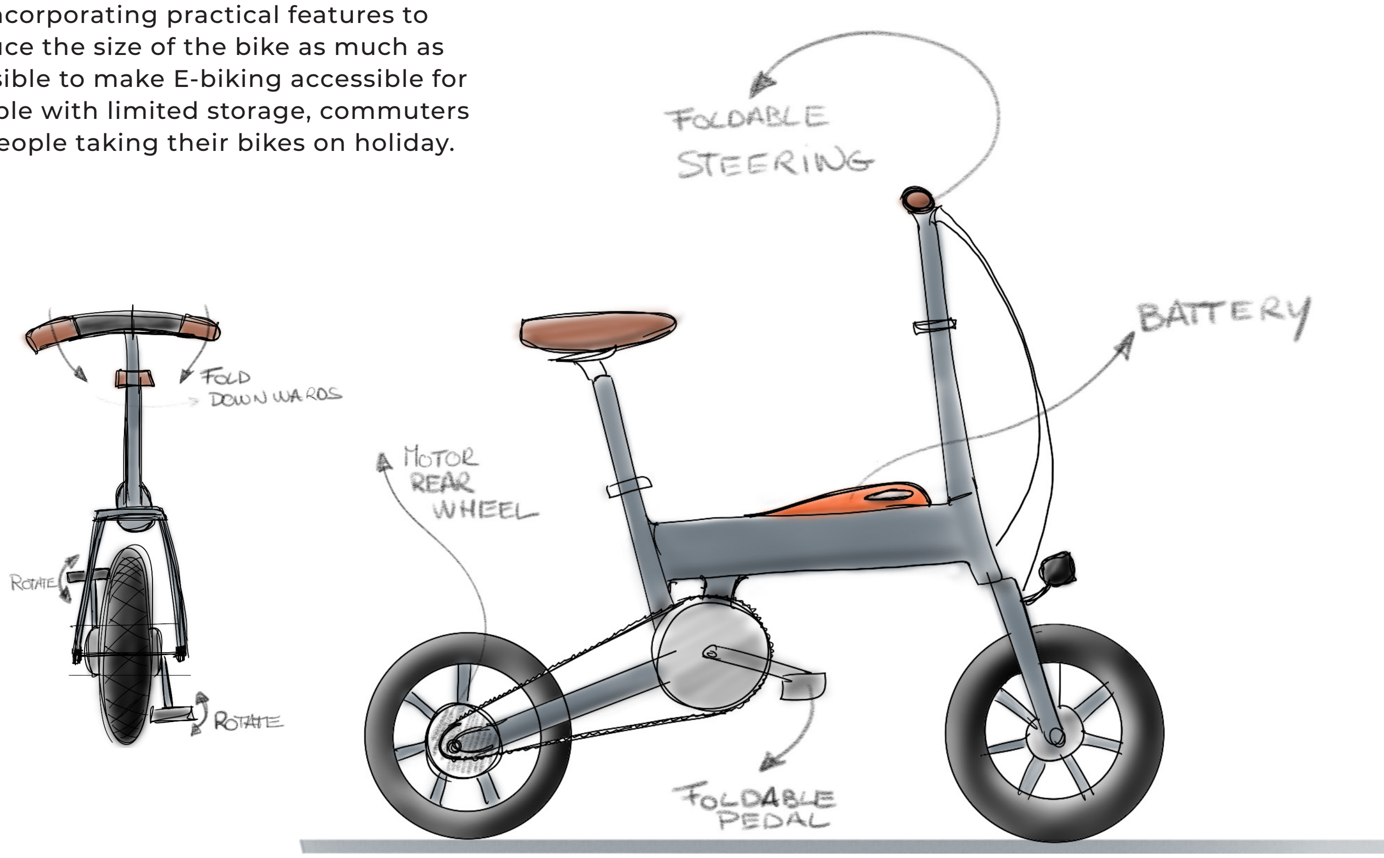
Knax is a build-your-own-bike kit. The kit includes connective pieces (in black) and different profiles and tubes (in grey) to build a bike in different shapes and sizes. The concept is largely inspired by a Dutch brand called Infento. This concept calls the user to use their creativity and build their own vehicle which they can modify over time with extension kits.

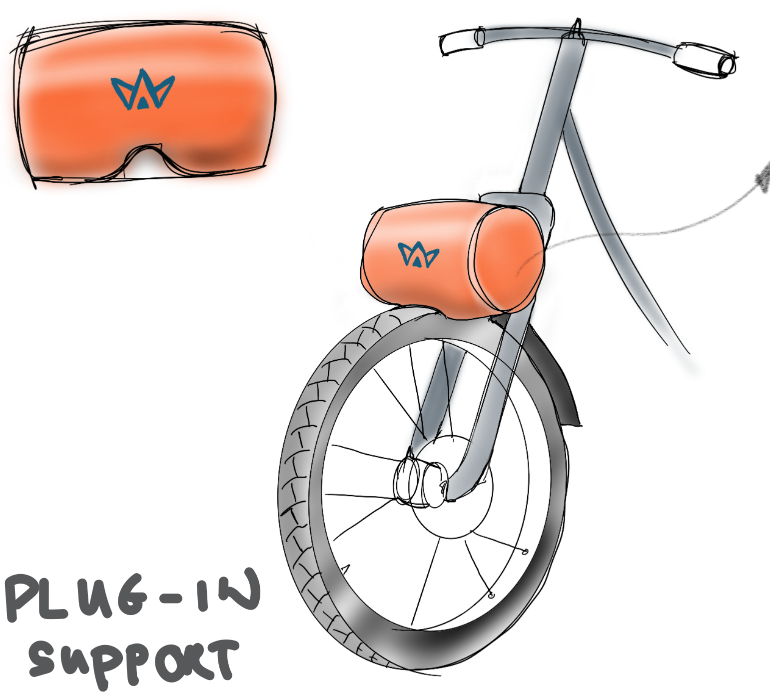
CLASSIC PEDELEC

Classic Pedelec is an alternative to the speed pedelecs currently available on the market. These E-bikes mostly have a modern and sporty look with high-tech materials and features. This concept is a marriage between a classical looking frame and high-tech performance. With a hidden battery and the option between a mid-motor or hub-motor in combination with a classic steel frame and customizable accessories, the concept aims at targeting a market segment of bike purists and fanatics.

Mini Foldable is the entry of Bayck on the fold-able bike market. This concepts aims at producing a pocket size E-bike for the portfolio of the company. The focus would lie on reducing size of the battery and other electronics as well as incorporating practical features to reduce the size of the bike as much as possible to make E-biking accessible for people with limited storage, commuters or people taking their bikes on holiday.

MINI FOLDABLE



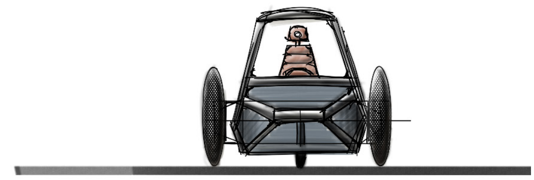


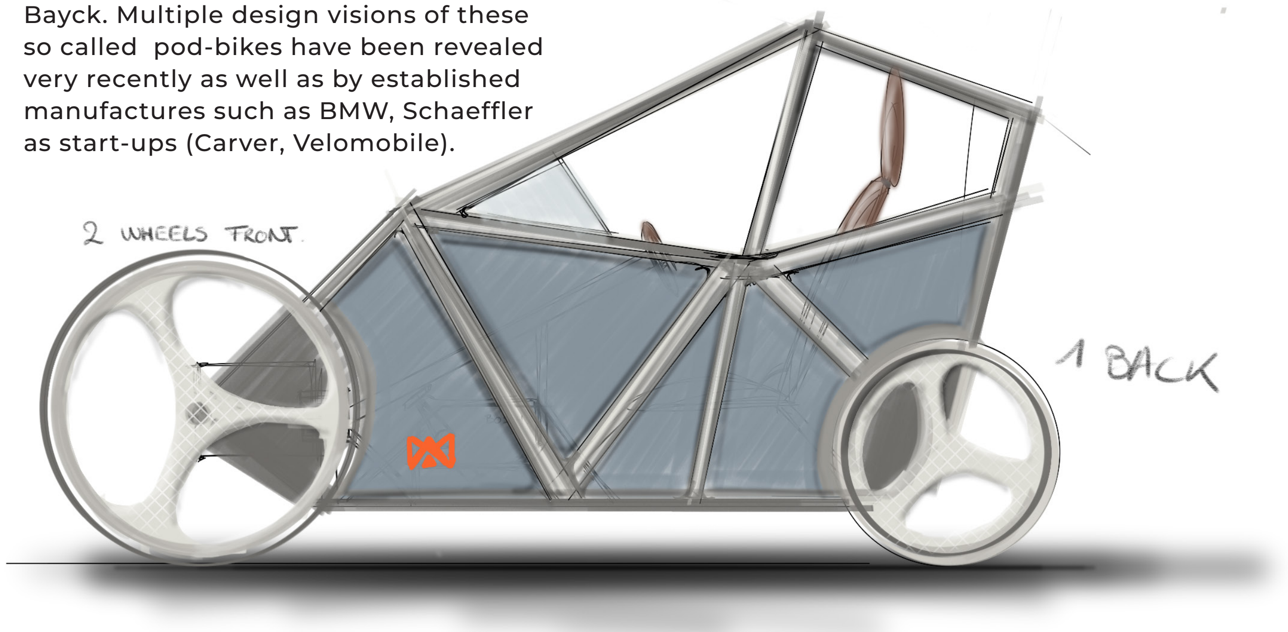
PLUG-IN SUPPORT

Plug-in Support is a device that can be placed on any bike to transform it into an E-bike. This concept looks like the revival of the forgotten Solex.
The main advantage of a completely removable pedal support is the fact that you can remove the valuable and vulnerable electronics from the bike. The concern raised during discussion is that electric motors are most efficient placed to the centre of rotation: an E-motor works best at high torque rather than high speed. Maybe the plug-in motor should be placed closer to the hub.

E-KART

E-kart is an hybrid between an e-bike and a car. This concept aims at making small commutes more exciting and comfortable. This idea of merging a bike and a small car is nothing new but has never reached a broad consumer market. The recent appearance of light electric vehicles in different forms and shapes in urban areas has set the tone for more to come. The E-kart could serve as a conceptual design vision for Bayck. Multiple design visions of these so called pod-bikes have been revealed very recently as well as by established manufactures such as BMW, Schaeffler as start-ups (Carver, Velomobile).

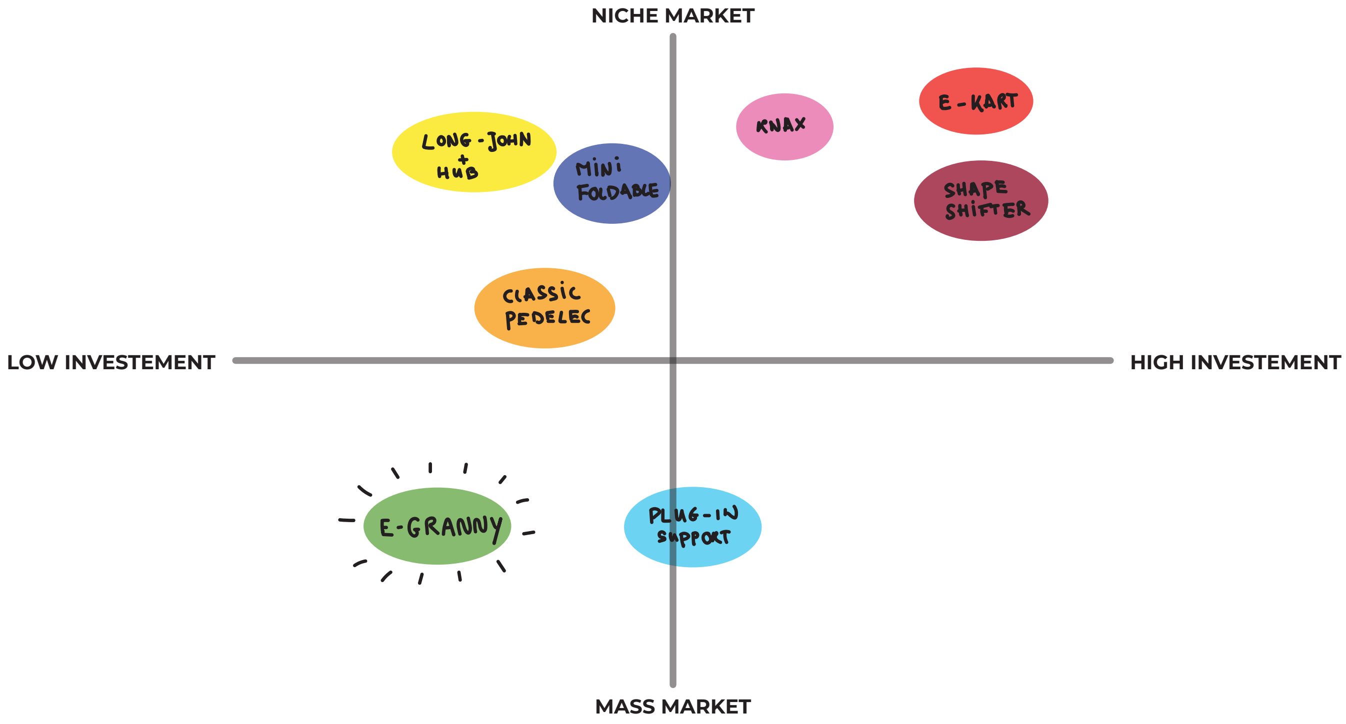




E-GRANNY

E-Granny is the marriage between the absolute archetype of bikes (the Dutch “Oma fiets”) and new technologies. Most of recent E-bikes available on the market are charged with expensive and complex hardware/electronics, making them vulnerable and expensive.
This concept aims at reducing the complexity of e-bikes: This is done by separating the electronics from the bike.
The E-Granny is meant to be used for small daily commutes. Therefore, a smaller battery is sufficient.

CONCEPT MATRIX



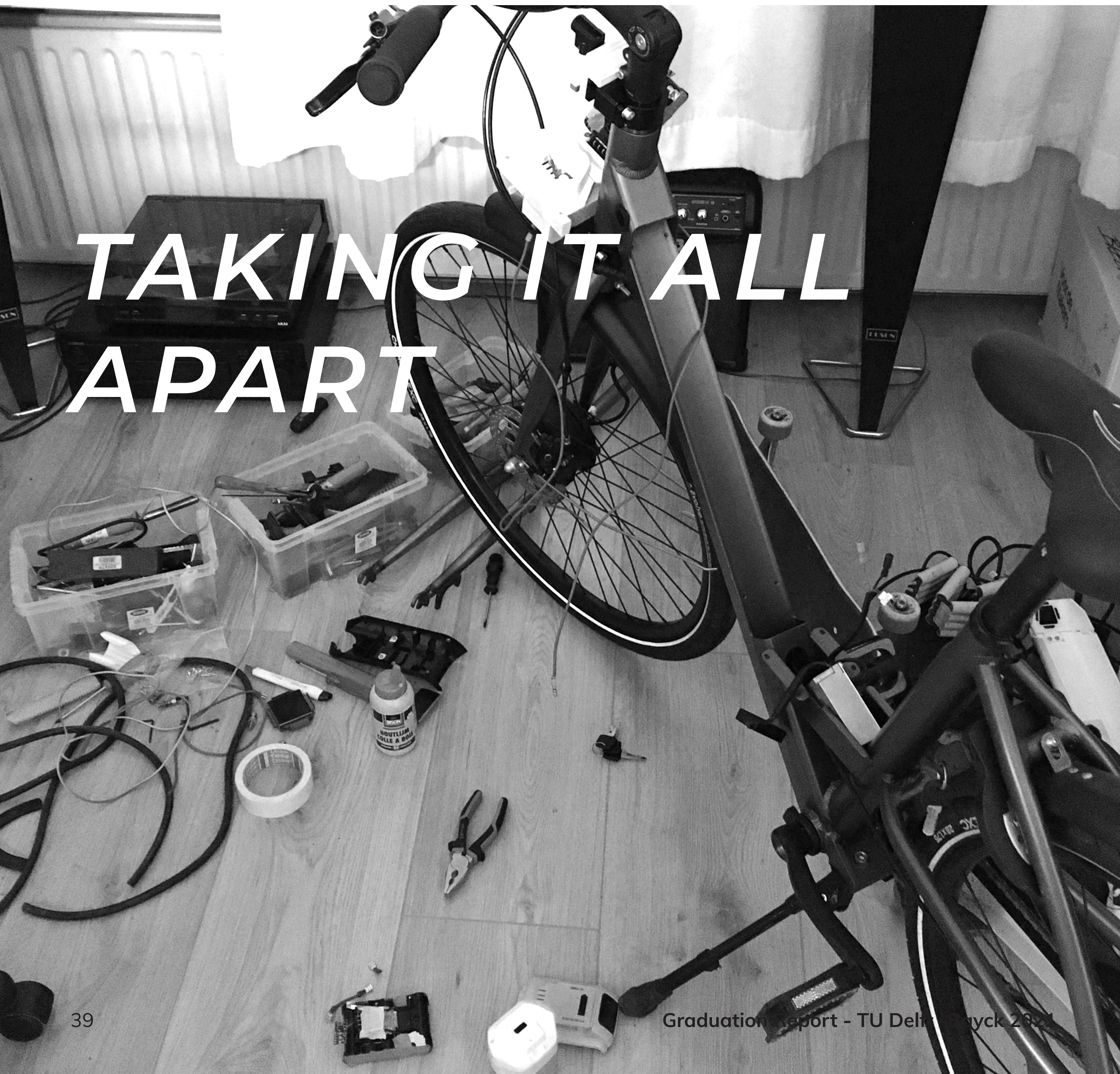
At this point in the ideation process, the strengths, weaknesses and opportunities of each concept is discussed with the team.
Since the company is really small and disposing on very limited resources, the team favours a solution that requires low investment and is applicable to a broad market.
It is decided to build a matrix with two axis: market and investment. Through discussion, the concepts are placed within the graph relatively to each other.
The E-Granny concept is placed the furthest in broad market and low investment and therefore chosen as the concept to be developed further.

Bayck 1 as reference

Before starting designing a new Bayck product, It is needed to understand how an e-bike actually works, which are the vital components and how they operate. It is also valuable to understand how Bayck 1 is constructed.
Therefore, an existing e-bike is stripped from its hardware and electronics; the electronics are completely disassembled to have a look what is inside.
The placement of the components on different locations on the current bike is identified, new placement alternatives with respect to the new concept are discussed.

CONCEPT DEFINITION

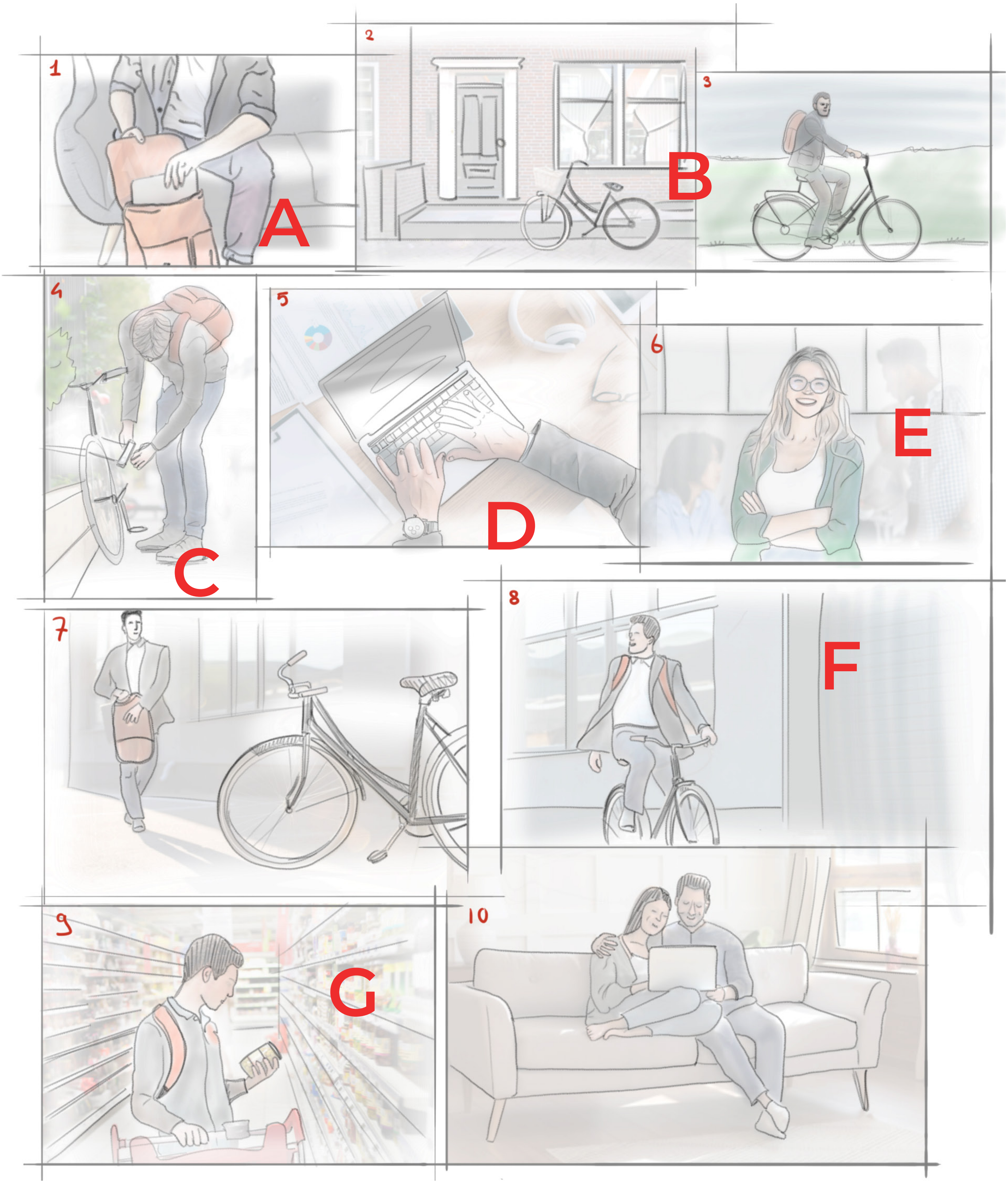
This chapter helps understanding how an E-bike works, how it is used and what modifications could be made. First of all, a story-board depicting the ideal use scenario is drawn.
After that, we take a deep dive in the technical functioning of the E-bike, and how we could redesign or move the components to get as close as possible to the ultimate desired use.
The chapter is concluded with the Program of Requirement, that is used as design frame for the Design Delivery part.



TAKING IT ALL APART

STORYBOARD

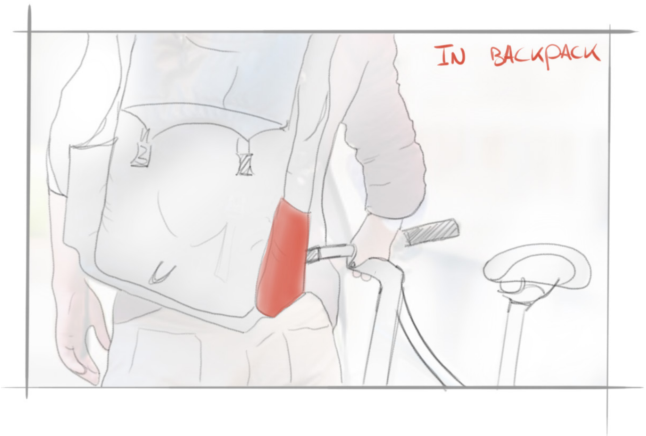
A storyboard is made to show how the products is meant to be used. The storyboard seen below depicts a day of a typical user; During the day, the user encounters multiple interaction moments with the product. We focus on these interactions to get a better understanding on how the product is intended to be used. This storyboard is made together with the Bayck team and depicts the ultimate desired situation. Former knowledge about what is technically feasible is put aside for this exercise. **The resulting concept from this storyboard is set as the design vision of Bayck, the concessions made in order to make the design feasible become the iteration steps towards this vision.**



EVENTS AND PRODUCT INTERACTIONS

1: Preparation
The user prepares himself to leave, for a day of work at a near co-working spot in the city. The device has been fully charged during the night. The user prepares the device for use.

Interaction A:



The device is taken from the charger, fully charged and ready for use. The device is small enough to fit in a backpack or pocket.

2: Leaving
The user is leaving the house and is about to use his bike. The user mounts the device and leaves.

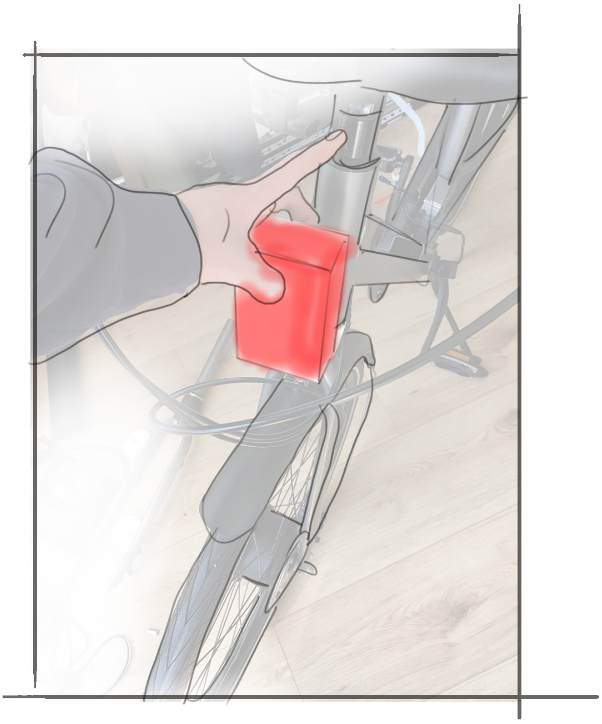
Interaction B:

The device is placed on the bike. The connection is made and the bike is ready for use. The concept is about the essential of biking, the interface and display are completely removed from the concept. The device's placement must empower the user to place and remove it easily from the bike.

3: Cycling to work
The user cycles towards the working place, located within 10 km of his house.
The device should not distract the user while biking.

4: Arrival
The user arrives at destination; he locks his bike and removes the device which he takes with him inside.

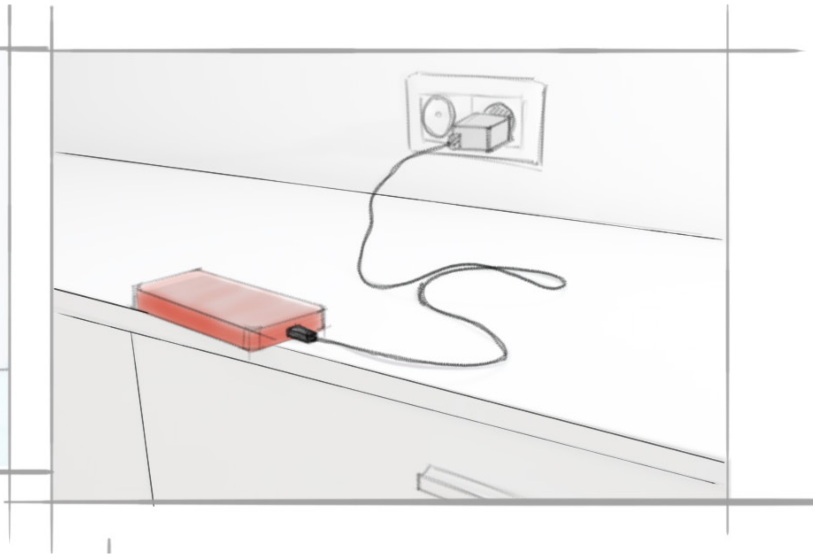
Interaction C:



The device is removed from the bicycle with one hand, and can be put in the backpack or pocket again.
When the battery is removed, only the motor remains on the bike, most of the vital electronics needed to operate the bike are included in the device.

5: At work
The user plugged the device for it to charge while he is working. This means the charger needs to be small and convenient enough to be taken to work.

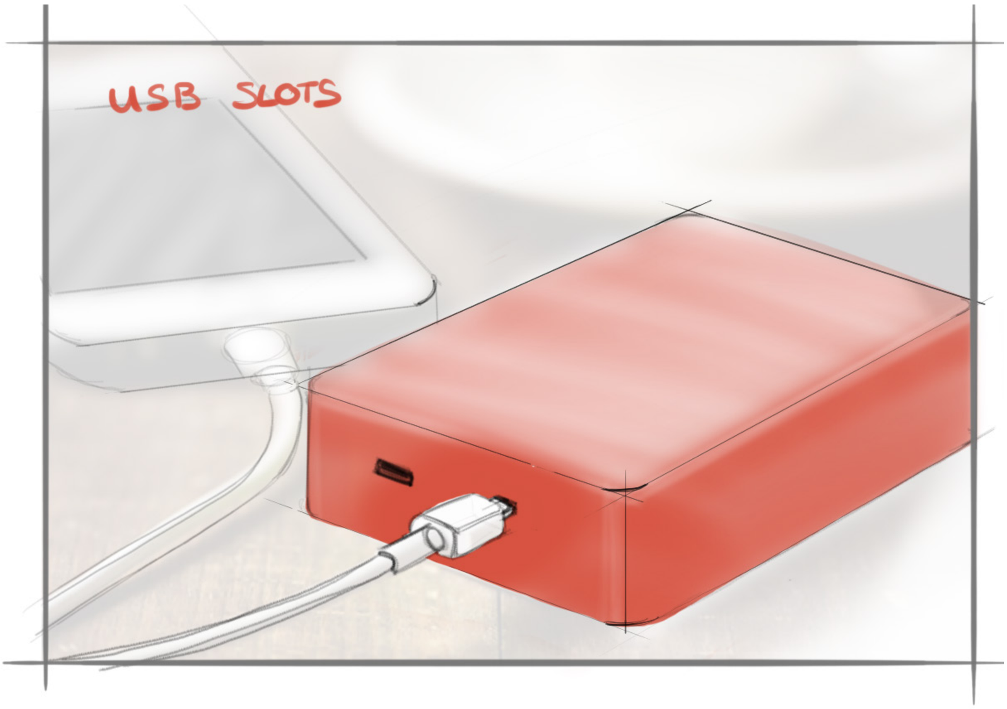
Interaction D:



The device can be charged through the USB-C PD slot, the device is fully charged within 3 hours. The device is compatible with laptop chargers, meaning a single charger is taken along for the day.

6: A co-worker needs to charge
A co-worker has a flat phone, she asks if she may charge her phone on the device.

Interaction E:

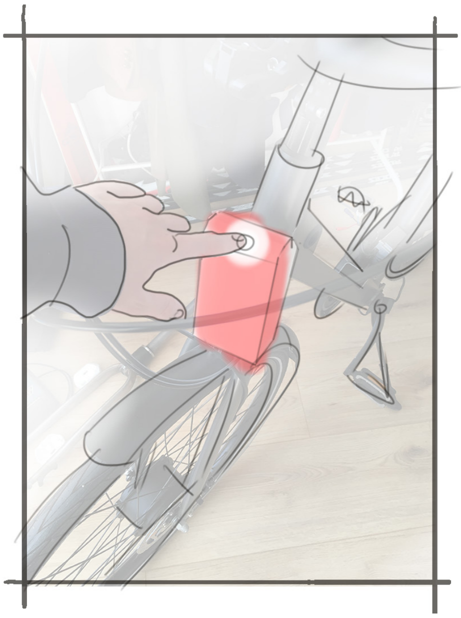


The USB-C PD port is reverse compatible, meaning the device is charged through this port, but can charge other devices as well.

7: Going home
At the end of the day, the user leaves, heading home, the device is placed on the bike in the same way as seen in interaction B.

8: Cycling back home
The user is cycling home at the fall of the day. He turns on the lamp within the bike module to be seen.

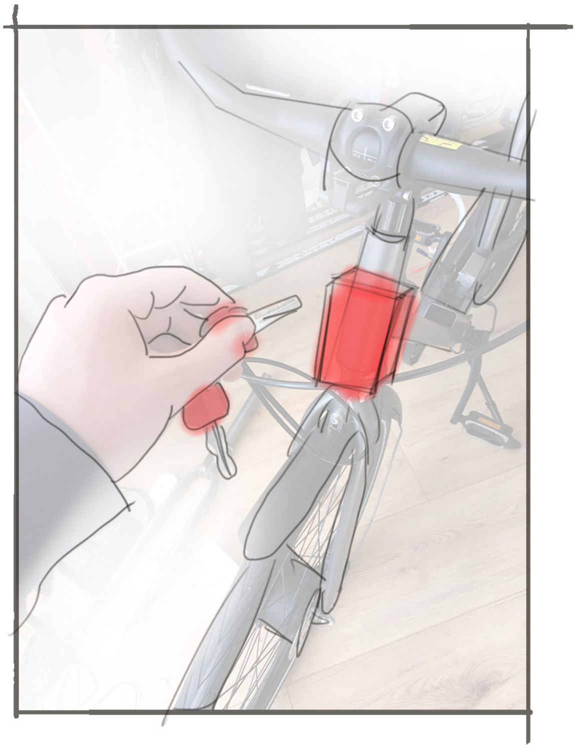
Interaction F:



The lamp is turned on through a mechanical switch. The lamp is made out of LED's, which is powered by the powerpack.

9: Quick stop at the supermarket
The user makes a stop at the supermarket on the way home. The user leaves the device on bike during the brief moment he is inside. The device needs to be locked to prevent it from getting stolen.

Interaction G:

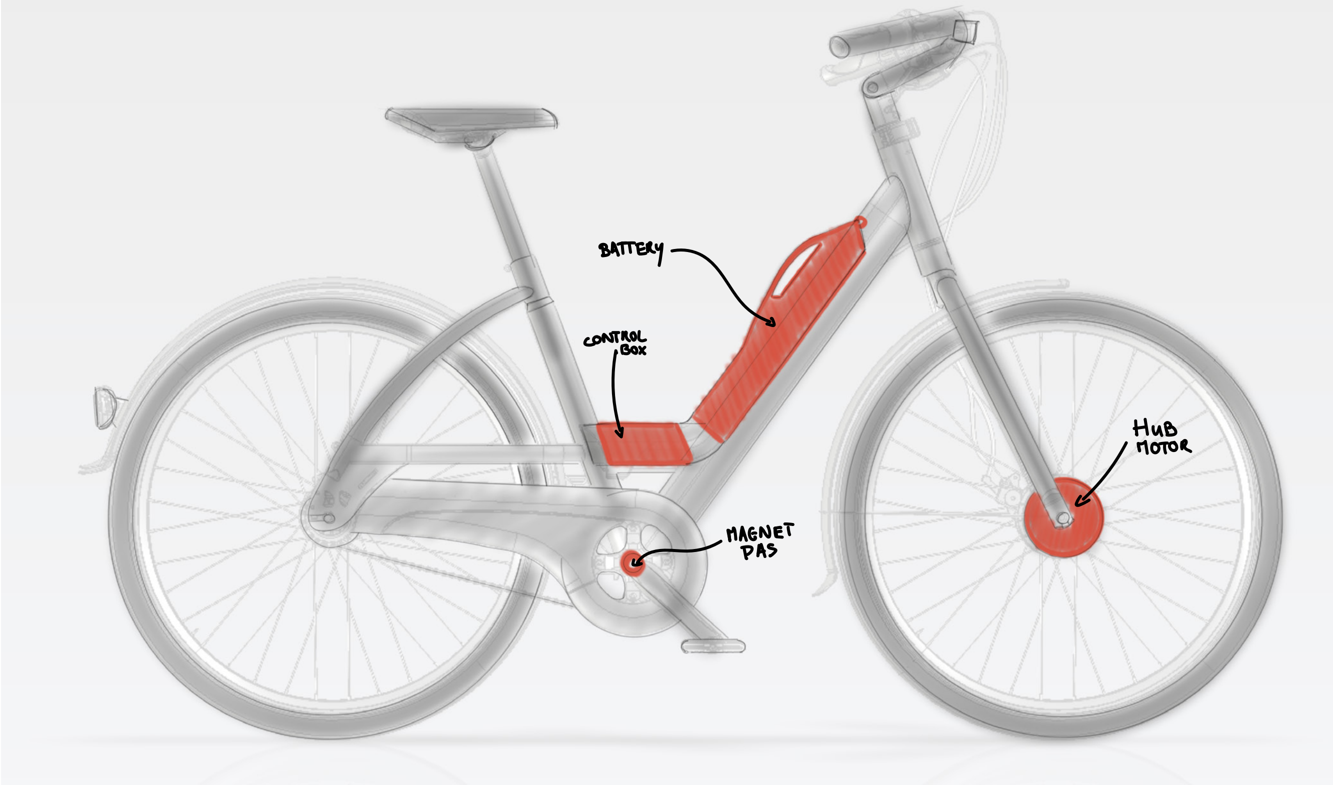


It is possible to lock the device with a physical key. It is nog possible to separate the power pack from the bike module when it is locked.

10: End of the day
The user arrived home; after taking the device off the bike, it is taken inside and put to charge the same way as during interaction D.

After identifying the wished use and interactions, the current set-up of Bayck 1 is studied to find out how this desired situation can be achieved and which changes should be made.

BAYCK 1 AS STARTING POINT



Bayck 1 set up

4 electronic components are identified as essential to the functioning of the e-bike: The motor, the control box, the battery and PAS sensor.
The battery and control box are both integrated in the shape of the down-tube, although the battery can be removed from the frame by the user whereas the control box not.
The (hub-)motor is placed in the front hub, in the front wheel.
The PAS sensor is placed on the pedal shaft.

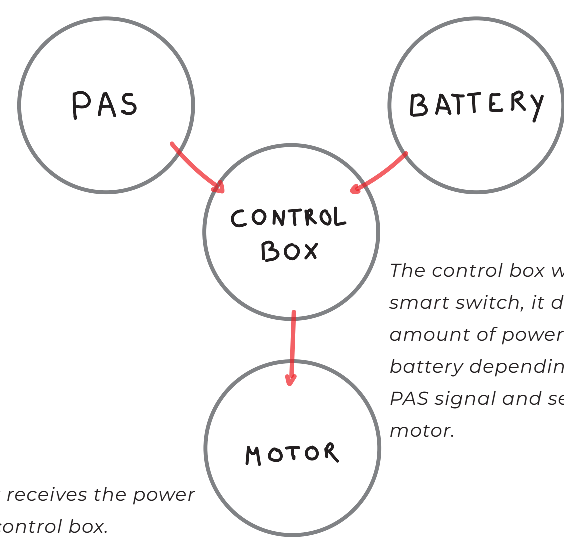
This e-bike has deliberately no display, the turning on/off and settings are done through an application on the user's phone paired to the control box through Blue-tooth.

Hardware wise: the bike is equipped with disc brakes front and rear, 5 shifts in the rear hub all operated with different handles left and right on the steering.

As a next step, the function and the relations between the electronic components is set-up:

PAS senses whether the user is pedalling or not (more about the PAS later in report). Signal is sent to the control box.

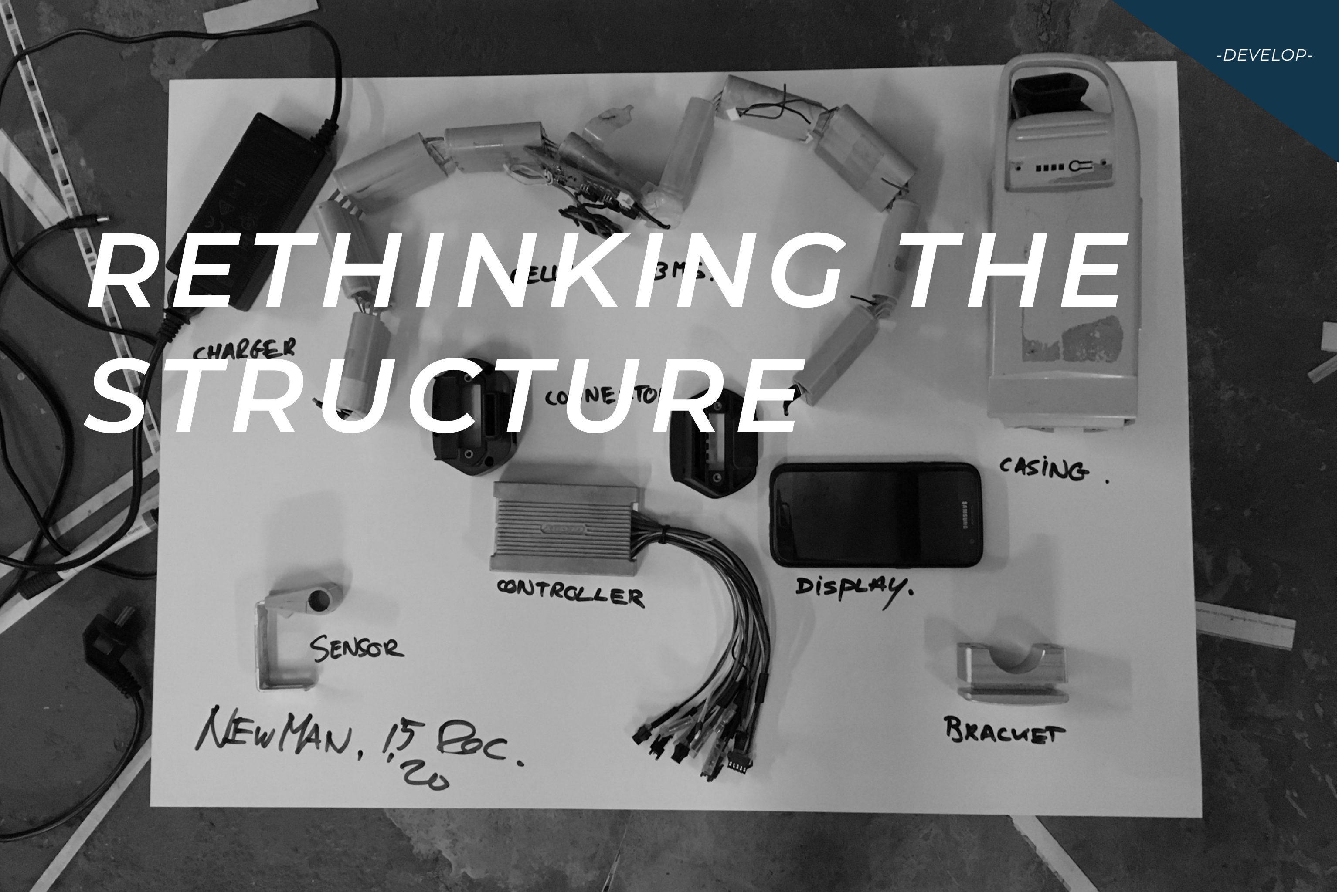
The battery is simply a power source, nothing fancy.



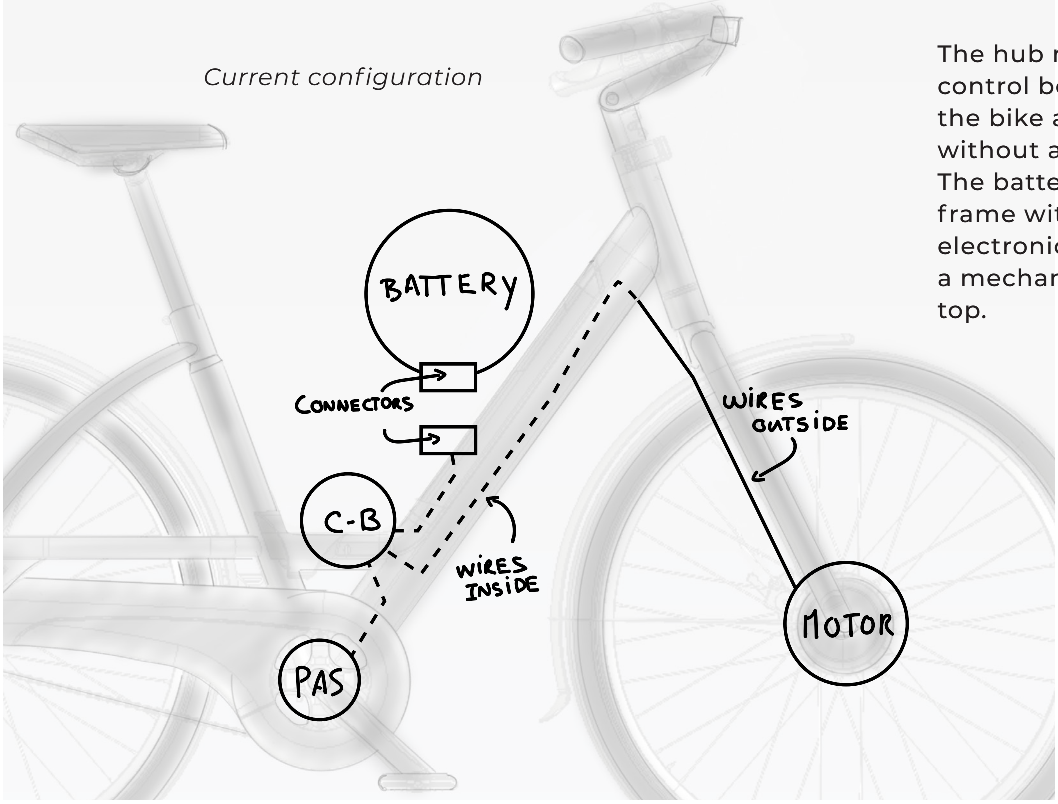
The control box works as a smart switch, it draws an amount of power from the battery depending on the PAS signal and sends it to the motor.

The motor receives the power from the control box. A "fixed" element on the hub and a rotating part connected to the spokes of the wheel.

RETHINKING THE STRUCTURE



After getting familiar with the necessary components, we observed how they are connected and to what.
A separation in the frame is made to understand the choices Bayck made regarding cable management for their first design.
The frame is static, whereas the fork rotates within the headset. The cables come out of the frame near de headset to cope with the rotation. The cable than runs down the fork, into the motor. A first step in the redesign is limit the cables between rotating parts.



The hub motor, PAS and control box are mounted to the bike and not removable without appropriate tooling. The battery is connected to the frame with a connector for the electronics at the bottom and a mechanical connector at the top.

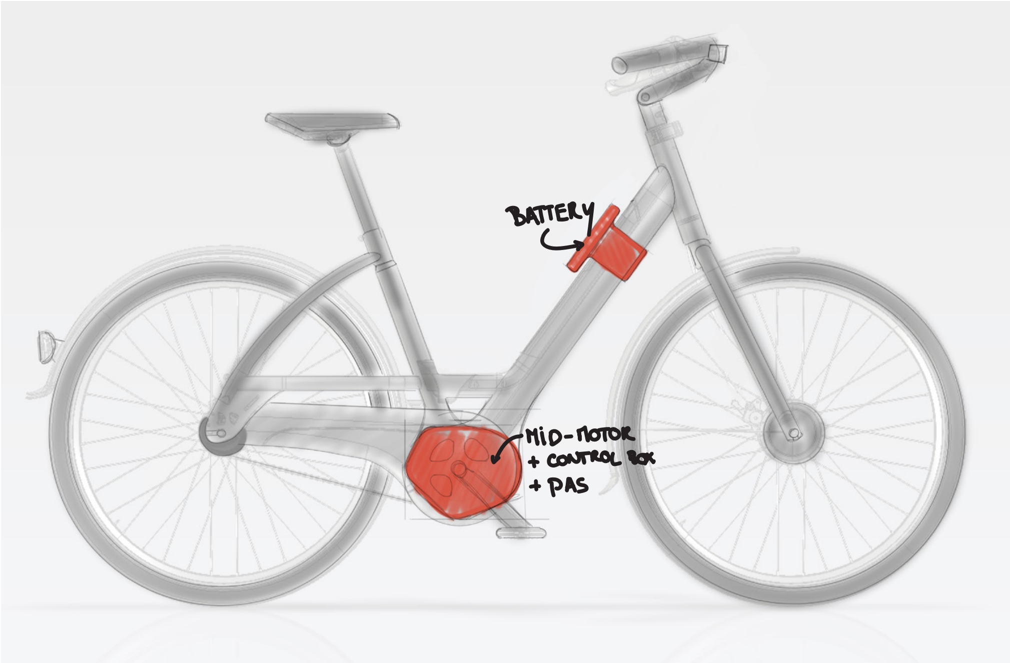
Cable management

Frame exit hole

Since the frame and the fork are two rotating elements relative to each other, it is not possible (at least very difficult) to run the cables through the inside of the tubes. The cables coming from the control box are coming out of the frame through the whole seen on the left, near the point where the down-tube is connected to the headset.
The rotation of the fork is making the cables slide in and out of the hole, making them to wear of.
The cables are tangled around the headset, crossing the brake cables going down as well. As pointed out during one of the emotion map interviews, the cables often get entangled, to great frustration of the user.

Cable tied to fork and motor plug

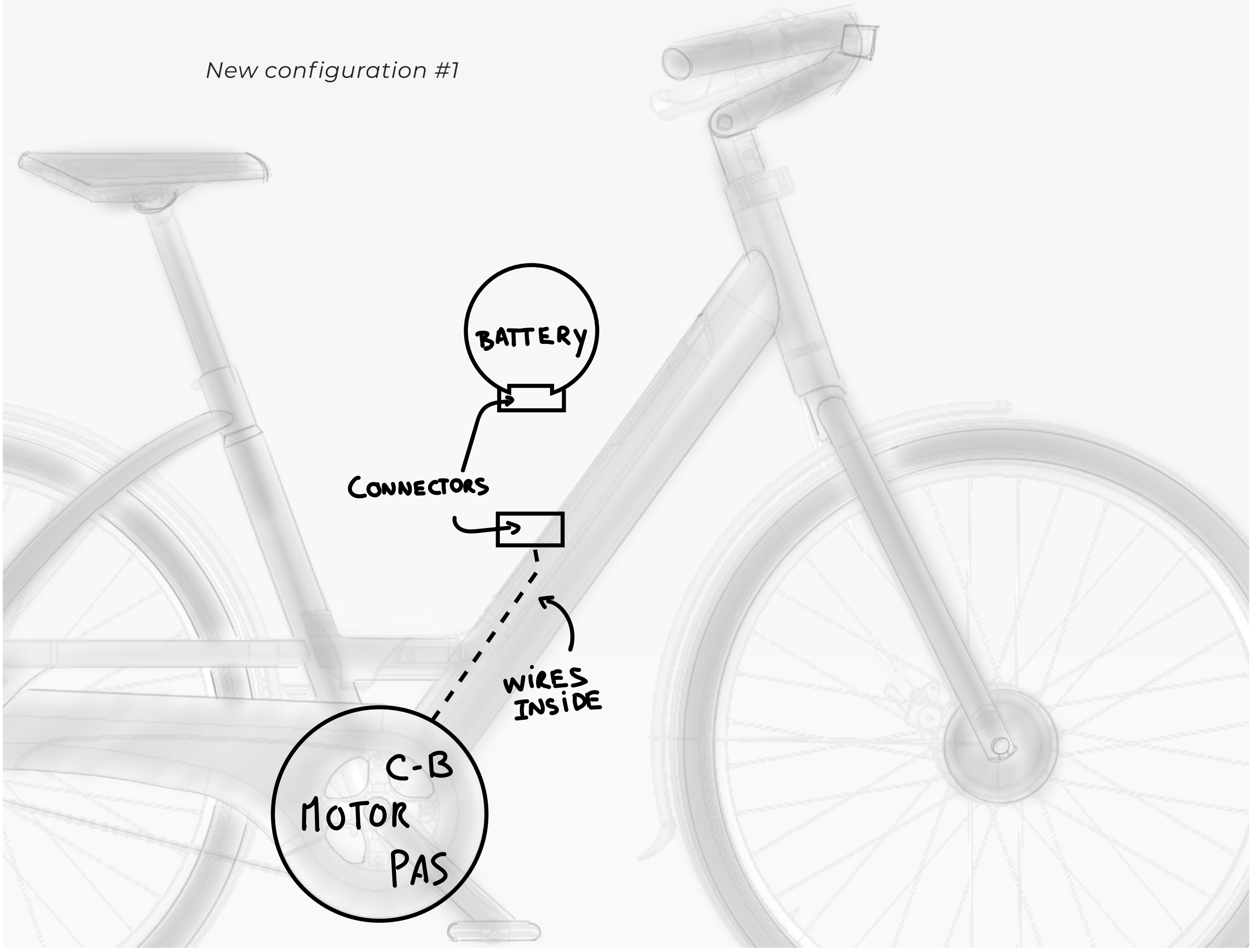
Structural rings are welded to the fork. The cable is tie-wrapped to these rings under and above the 9-pin plug that connects the motor to the control box cable.
The 9-pin plug is vulnerable and not well protected in this set-up.
The pins inside the plug are small and fragile; plus, the pins and hole have to be properly aligned without guidance in order to fit.
This connector is not ideal for fast plug and unplug on a daily basis. This observation influences the convenience and feasibility of a removable control box later in the process.



new Configuration #1

In this configuration, the control box, PAS and motor are regrouped in a mid-motor. The removable battery is placed on the down tube without altering the structure of the frame. The mid motor could for example a Bosch Active Line. The bottom of the frame has to be designed specifically to fit the shape of the motor.

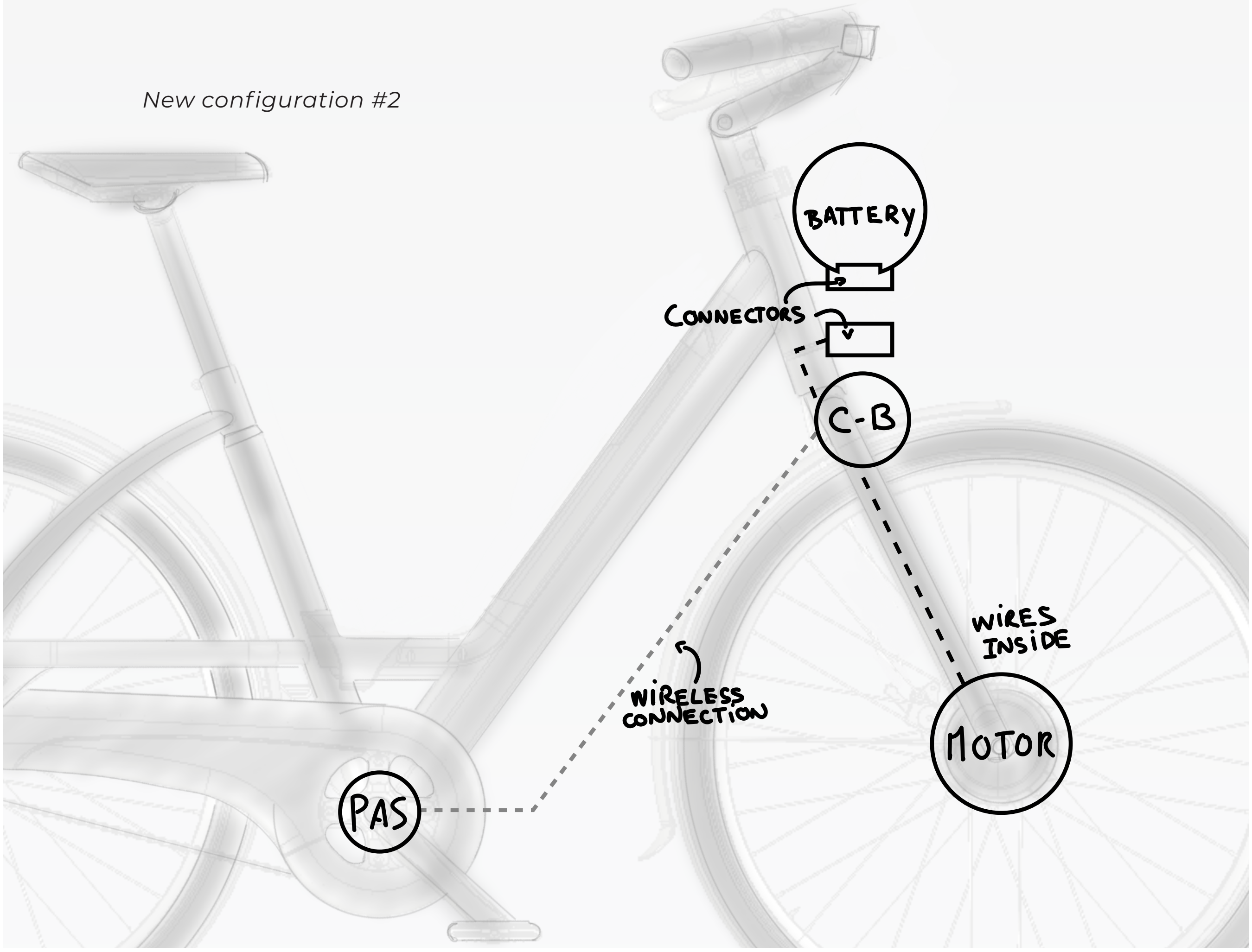
In this configuration, all the components are clustered in the frame; the wires are running through the inside of the down tube towards the connector.
The Battery is reduced in size compared to the battery of Bayck1.



new Configuration #2

In this configuration, The control box and removable battery are placed on the front fork, the hub motor on the front wheel.
The PAS remains on the pedal shaft; to prevent wires running from the PAS through the down-tube towards the control-box, a wireless solution is opted

New configuration #2



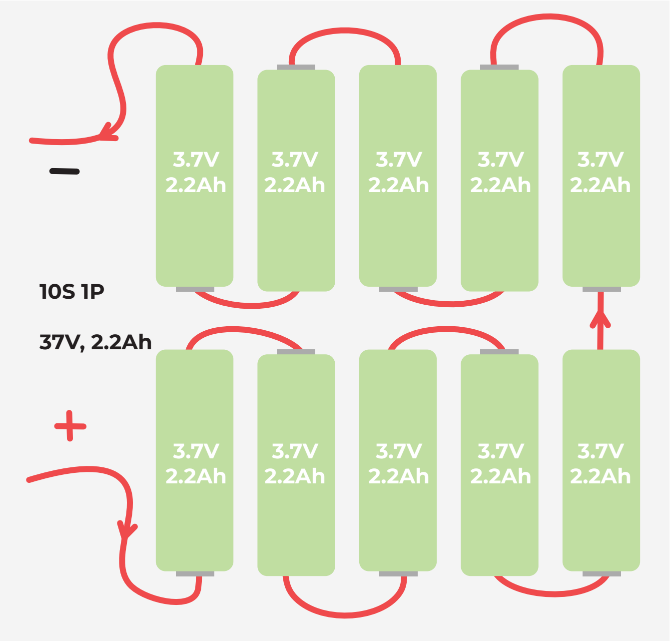
UNDERSTANDING THE COMPONENTS

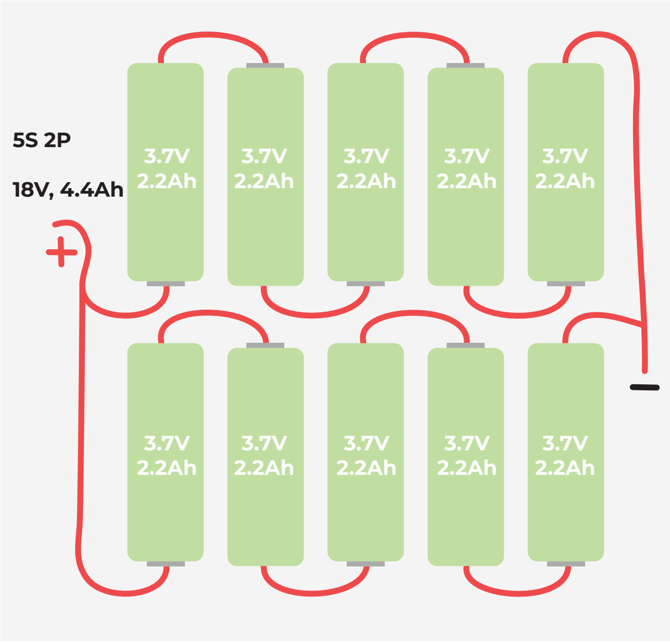
The Battery

Cell type
A battery is in fact a group of connected cells. The cells used by bike are most common lithium-ion cells available on the market. They are called 18650, have a nominal voltage of 3.7V and a capacity of 2.2Ah. Nominal voltage means the average voltage at which the battery operates. These cells are manufactured in China by third party companies (Samsung, Panasonic, Sony...) costing roughly around 2 Euro's a piece. A cell is a cylinder of 65mm high, and 18mm diameter. The cells are connected in series or parallel to obtain the wished voltage and capacity.

18650 cells

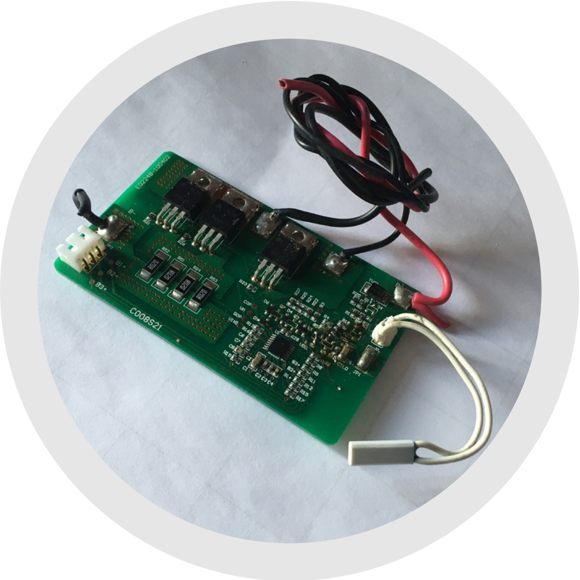
Series and parallel connections





Here above is demonstrated how different connection between the cells result in a different voltage and capacity. Voltage adds up when in series, capacity adds up when in parallel.
The number of possible combinations is limited: since the motor of the E-bike is 36V, the final voltage of the battery or battery combination should be equal to ±36V. Both a parallel or series connections require equal voltage between the cells or groups of cells. The minimum amount of cells required to make the system work is 10 cells, the total amount of cells could be either 10, 20, 40, 80, 160... and so forth. Bayck 1 has a 36V 8.8Ah battery; it is build out of 40 cells, 4 parallel series of 10 cells (10S4P).

Battery Management System
A BMS is needed to ensure all cells charge and discharge at the same rate. The BMS is wired to all the cells to measure the individual voltages and rectify the differences between the cells.



BMS

Voltage difference between the cells would result in over exploiting cells, creation of heat and ultimately, destruction of the cell. A BMS often includes features such as temperature measurement for safety, battery status indicators... A BMS's can be ordered of the shelf from battery manufacturers, but is commonly designed specifically for a battery design; the more cells you use, the bigger the BMS needs to be.

5-pin connector

Connection

The battery is connected to the frame through five connective pins. The two external pin are the positive and negatives poles of the battery, often called B+ and B-, two other pins are called TXD and RXD, meaning data transmission and data reception; think of temperature, status, etc...
The mysterious 5th pin has no name and is rarely attributed a function, the 5th pin is not in use on the Bayck 1 battery. The female slots are in the battery, the male pin are on the connected device. This convention can be seen on all external batteries, from phone batteries, to power-tool batteries.

Control box

Control box

As mentioned before, the control box is the servo of the E-bike. The control box is typically the thing that bike manufacturers do no develop themselves but integrate existing control boxes. It is remarkable that most bike manufacturers in fact use the same control boxes, maybe modify the software to fit their designs.
This "common" control box has next to the required connections (PAS, battery, motor), also added connectors for the display, brake assist, throttle, anti-theft, debug port and a few more. Most of these functions are not used in Bayck 1, taking up unnecessary space.
The production process of a control box is also a curious thing: The PCB plus components are put into an aluminium casing which is then filled with a resin to isolate and protect the electronics. If one single component breaks down, the whole controller can be thrown away.
Few e-bike manufacturers integrated custom made control boxes such as Van Moof to fit their design specifically and blend in with the shape of the bike.

The pedal assist sensor (PAS)

The PAS used on Bayck 1 is the most common and inexpensive system available: the magnetic sensor.
The system is mainly build out of two parts: the magnet and disc.
The magnet is fixed to the frame and producing a small magnetic field. The disc is fixed to the pedal shaft, rotating when the user pedals.
There are metal dots on the surface of the disc which slide across the magnet when the user is paddling. The passing dots disturb the magnetic field and create a small voltage change called the hall effect. The voltage change is transmitted to the control box and activates the motor.

PAS

Dotted disc and magnet

The control box activates the motor when 3 dots have passed the magnet, mostly because of security reasons. The response time of the motor can be shortened by adding more dots to the disc.

The motor

The motor on Bayck 1 is a 36V Bafang hub motor. It is a “brush-less” type meaning it does not offer much resistance when the pedal assistance is turned off.
The motor will be held as it is for this project and is considered to be out of scope for design modifications.
This motor will be used for the redesign as well.

Brush less hub motor

PERFORMANCE TESTS

One of the key elements of this concept, is to reduce the size of the battery; the company set the minimum km requirement at 15km range.
if we consider the specifications Bayck 1 shared on their website, one should be able to cycle at least 80km with the 36V 8.8Ah battery; This means that we should theoretically be able to cycle 20km with a 10 cell, 36V 2.2Ah battery.

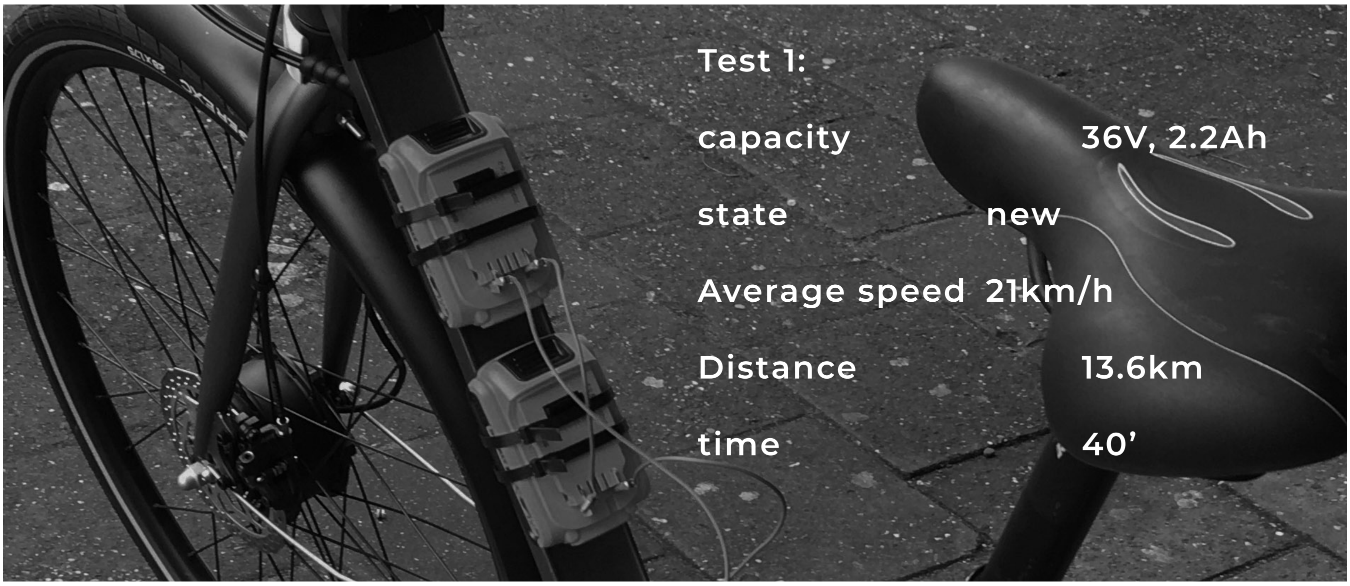
In order to test if this is true, a simple test set-up is made with two brand new DeWalt 18V 2.2Ah power tool batteries connected in series (becoming 36V, 2.2Ah) and mounted to the bike.

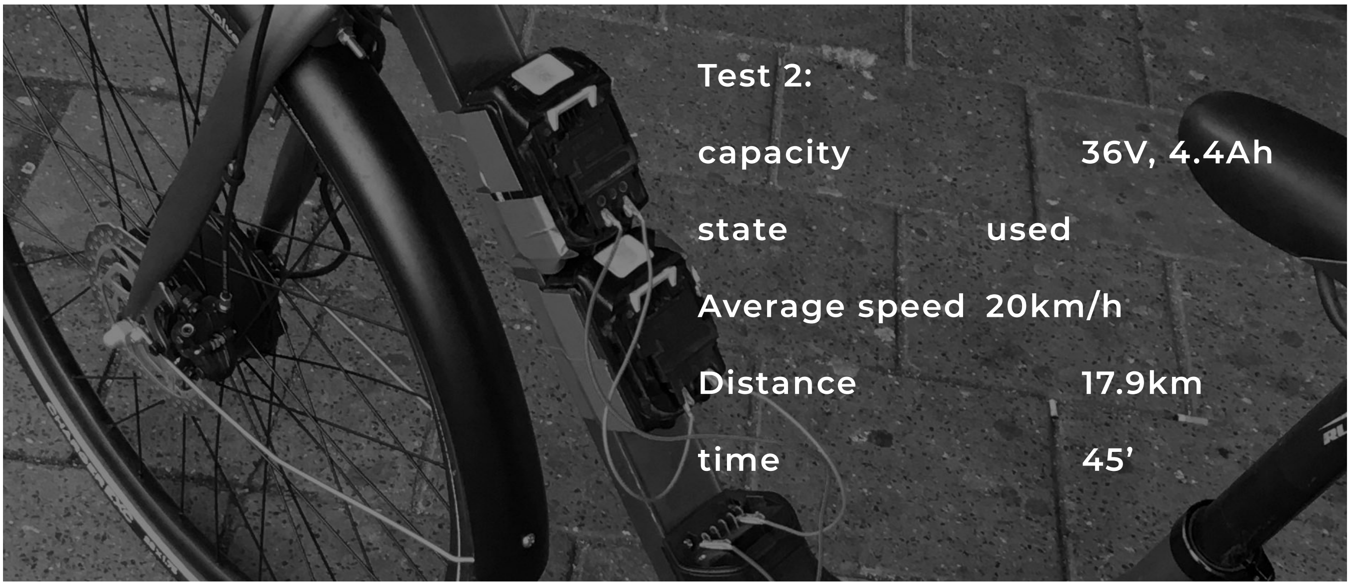
When fully charged, the voltage is at 42V, fully discharged at 32V.
The batteries are tested in a urban situation, in fair weather conditions (10 degrees) and pedal support level 2 out of 4.
Average speed 21 km/h, 40 minutes cycling, achieved distance: 13,60km until shut down.

Considering that the batteries are brand new and that Li-ion batteries are known to have a severe performance drop over time, the result is not satisfactory.

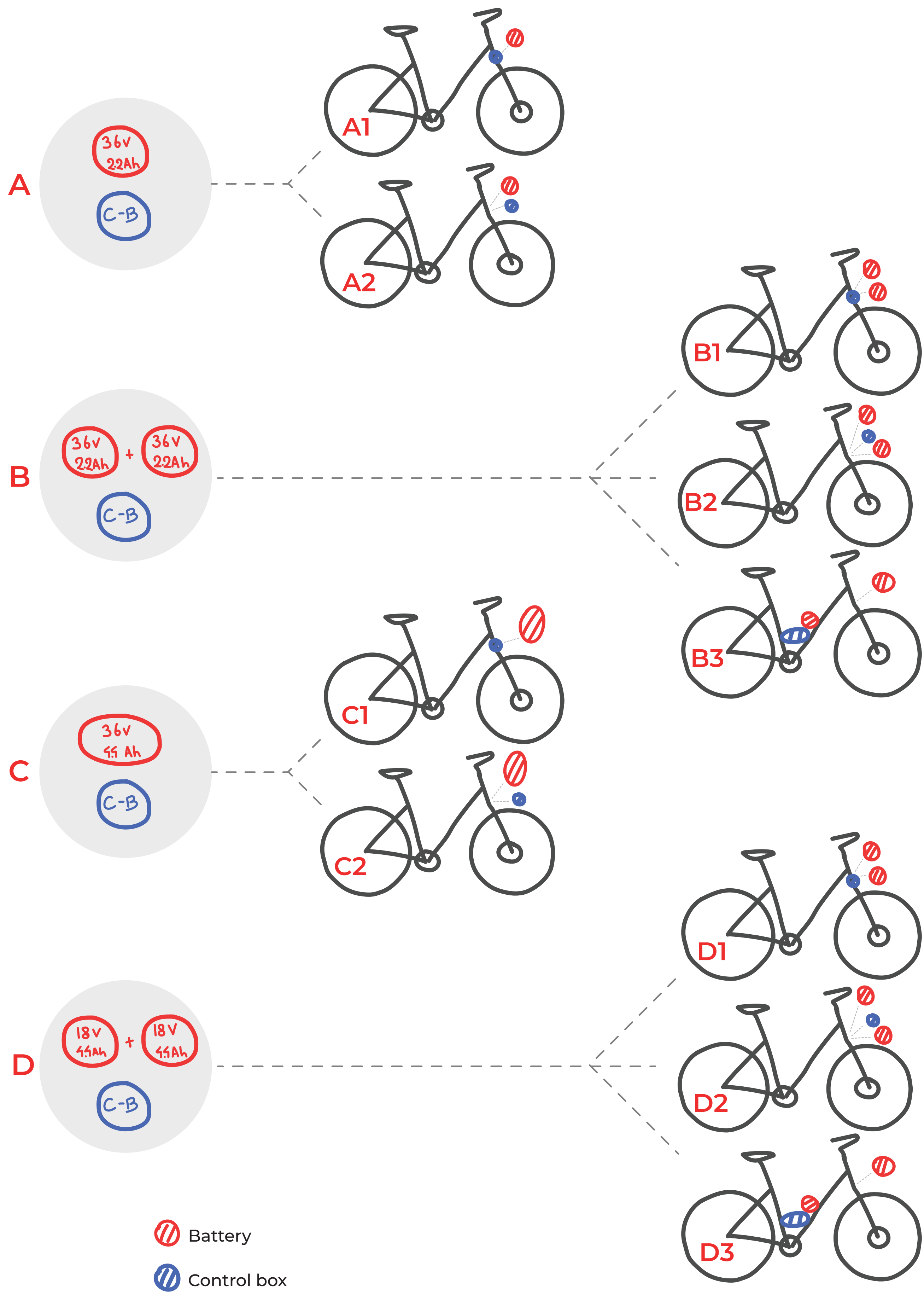
Therefore, a second performance test is set-up with more challenging conditions.
Two 18V 4.4Ah Makita batteries are used which are more than 5 years old.
When fully charged, the voltage is at 42V, fully discharged at 32V.
The batteries are tested in a urban situation, in cold weather conditions (0 degrees) and pedal support level 2 out of 4.
Average speed 20 km/h, 45 minutes cycling, achieved distance: 17.9km until shut down.

The conclusion of these tests is that the 10 cell battery at 36V, 2.2Ah does not meet the distance requirement set by the client, whereas the 20 cells, 36V 4.4Ah battery do.
Therefore the second set-up is selected for the concept.





CAPACITY AND PLACEMENT SELECTION

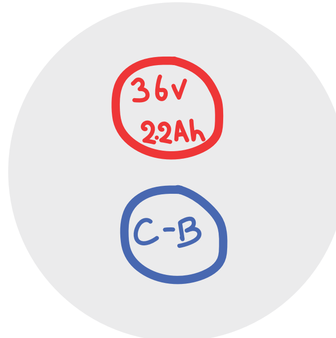


set-up A

Composed of a single 36V 2.2Ah battery, 10 cells in series.
The Bayck vision is formed around this set-up: a singular and small package for the ultimate convenience of the user. The capacity of this set-up is tested in performance test 1 but the distance results are not satisfactory (13km with brand new batteries). Therefore, other alternatives with more capacity are brought in.

A1: Integrated CB, removable battery
A2: Removable CB and battery

A

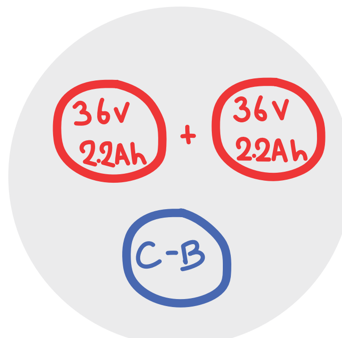


Set-up B

Composed of two 36V 2.2Ah batteries, both 10 cells in series.
The main advantage of having two 36V batteries instead of two 18V batteries: remove one battery and the bike still works, since it is a 36V motor.

B1: Integrated CB, two removable batteries
B2: Removable CB and batteries
B3: integrated CB and one battery, removable battery

B

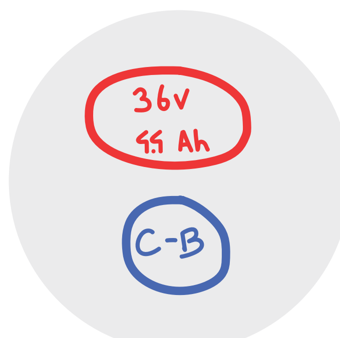


Set-up C

A single 36V 4.4Ah battery, two series of 10 cells in parallel.
The client indicates that the package of this set-up would be too large considering the storyboard. Therefore, this option is discarded.

C1: Integrated CB, removable battery
C2: Removable CB and battery

C

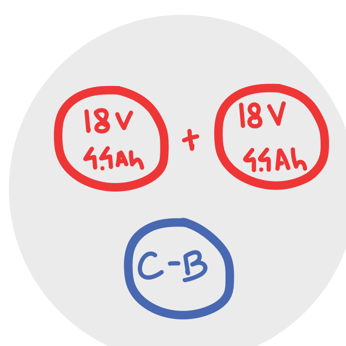


Set-Up D

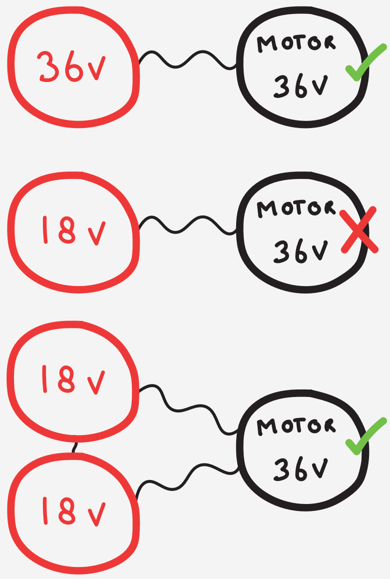
Composed of two 18V 4.4Ah batteries, both two parallel series of 5 cells.
D1 and D3 are selected as following steps within the roadmap.
This set up has been tested in a performance test 2 with a distance of 16km (with old batteries) and satisfies the distance requirement.

D1: Integrated CB, two removable batteries
D2: Removable CB and batteries
D3: integrated CB and one battery, removable battery

D



Using a 36V motor with 36V and 18V batteries



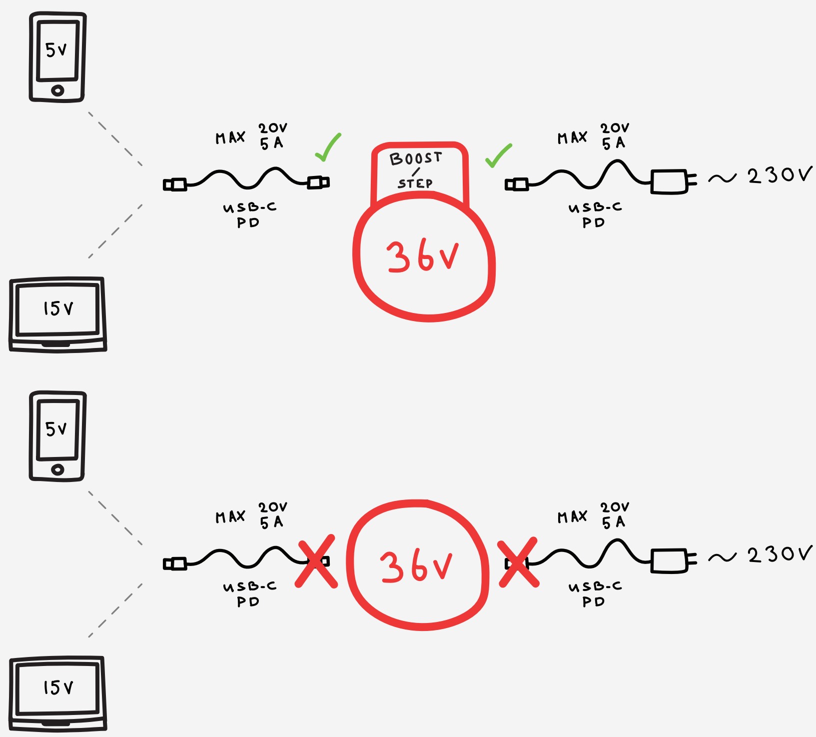
18V VS 36V

As shown in the storyboards, the battery should be compatible with USB-C for charging plus charging external devices such as smartphones or laptops. The maximum allowed voltage through USB-C cables and ports is 20V. Therefore, set-up A, B and C are not compatible with USB-C. A step-up (boost) and step down converter are needed to convert up or down the incoming and outgoing voltage. Adding these necessary modules to the set-up would increase the size of the packages, as well as double the charging time; in addition to that, they can release a significant amount of heat.

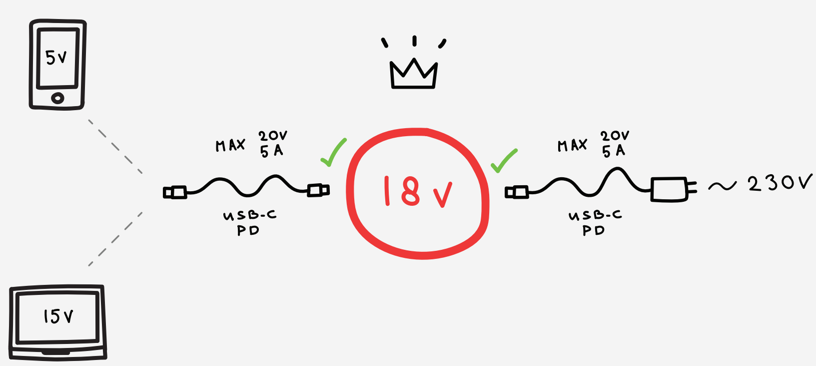
The downside of 18V batteries compared to 36V batteries is that it is not possible to use the bike when one of the two battery is removed (since it is a 36V motor).

The direct compatibility with external devices without the added complexity of boost / step-down conversion is identified as most important; Therefore, set-up D (18V) is selected.

Connecting an 36V battery with USB-C

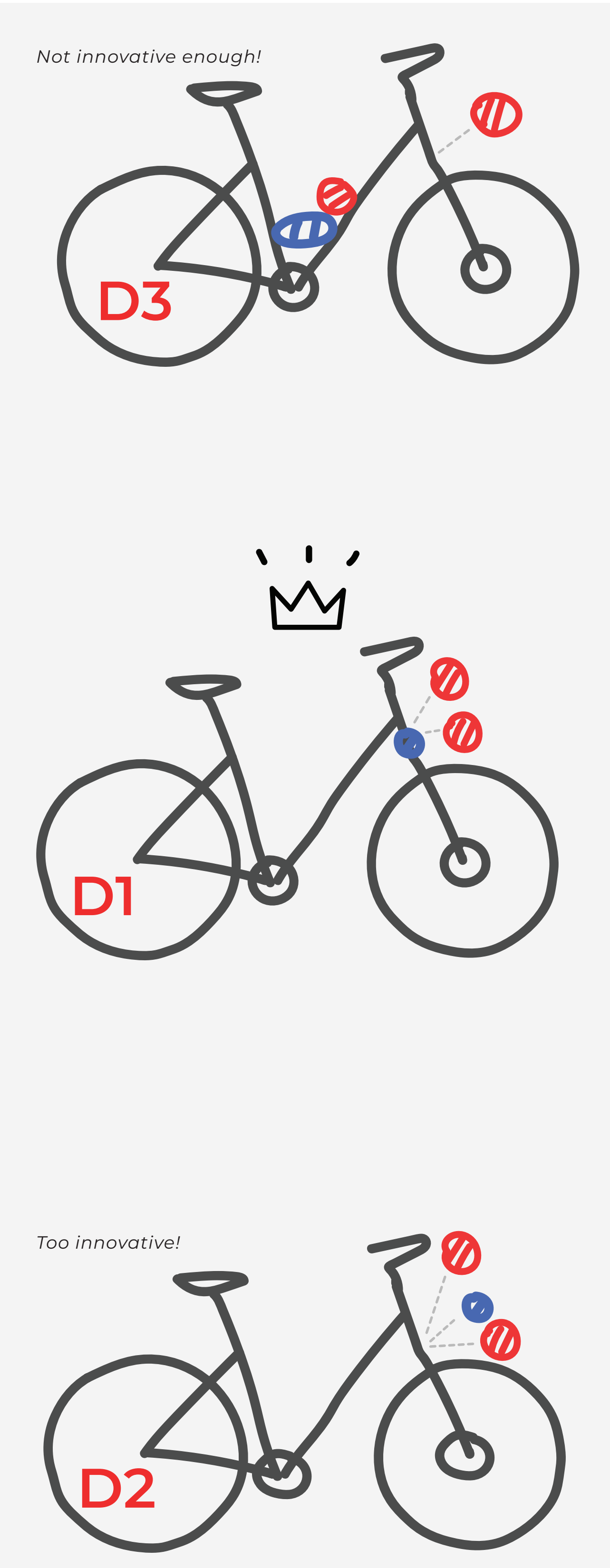


Connecting a 18V battery with USB-C



FINAL SET-UP SELECTION FOR CONCEPT DEVELOPMENT

At this point, three options remain. The difference between these options is their gradually increasing complexity compared to the current set-up of Bayck 1. Even though the selection of one concept is made for the ongoing of this project, the other options aid to build the roadmap.



D3 is the first logical step from Bayck 1: control box stays at same place, connected to the PAS, the battery is divided in two, half is placed on the steering, that is the battery the user can use as the detachable / multi purpose battery. This option is feasible and requires the least innovation on behalf of the company. On the other hand, this option is the furthest away from the vision and the ambition to simplify the e-bike.

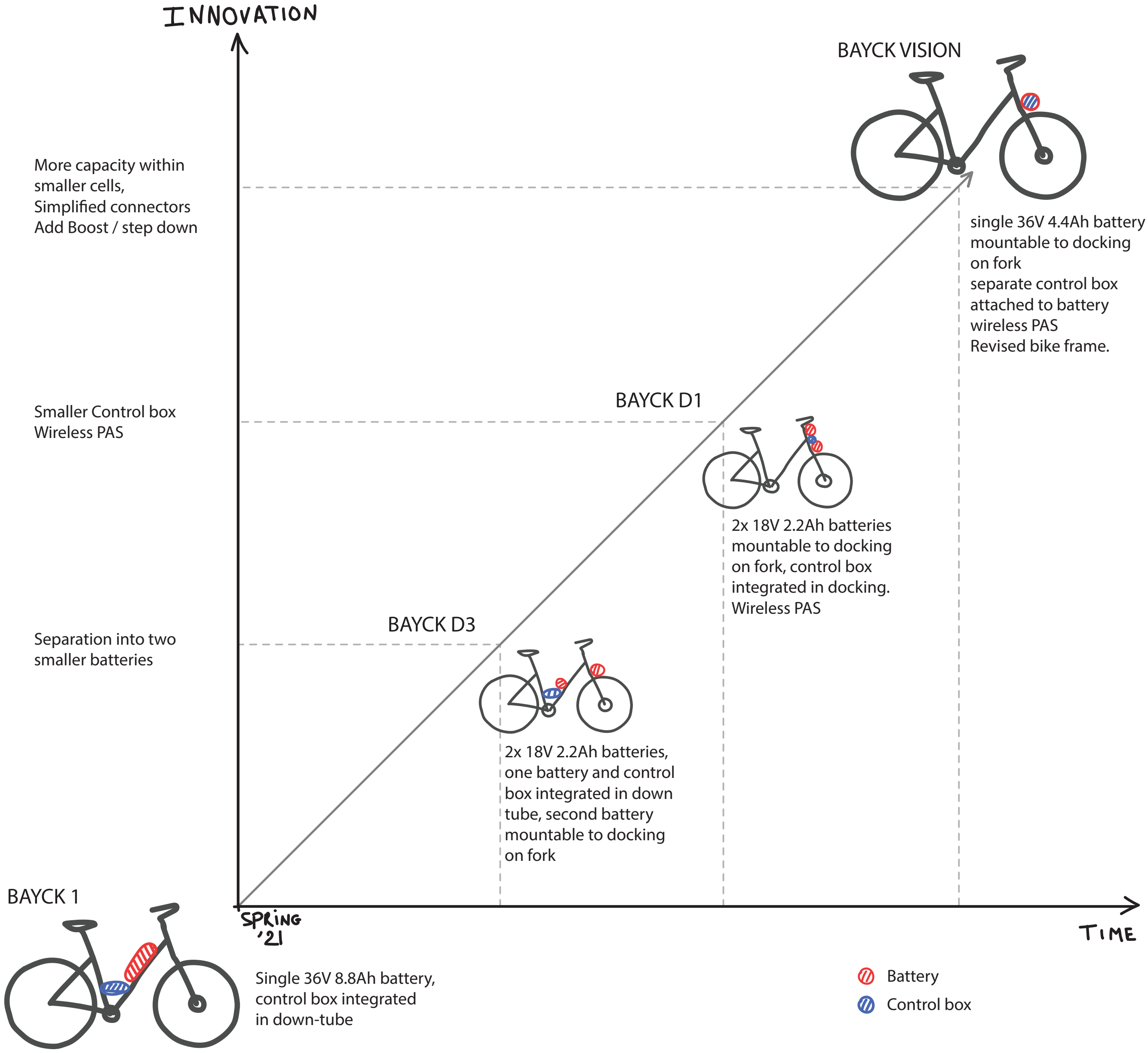
D1 regroups the control box and batteries on the fork/steering, removing all wires going from frame to fork. The control box is integrated in the battery docking station.

D2 takes the separation one step further with a removable control box. The problem is with this configuration is that the 9-pin connector between the control box and motor would require a redesign in order for it to be (un-) plugged more easily than it currently is. Developing a new connector is not the current ambition of the company.

To conclude, D1 is identified as the sweet-spot between feasibility and innovativeness. This option requires three crucial modifications from the current design: a wireless PAS, A smaller control box and the division of the battery into two external batteries. The company declared that these modifications are within the limits of their resources and ambitions.
D1 is selected as the configuration for the ongoing of this design project.

The required innovations identified in these options are used to build a roadmap. What is required to reach the design vision?

ROADMAP



Innovating up the road

Bayck vision is initially set as the goal of this project to be achieved in terms of user interaction: a small but powerful battery allowing the user to cycle over 20km. Compact enough to be carried around easily including a removable control box to separate the bike and electronics as much as possible.
Multiple innovation steps within the company as well as external developments are required to be take place before reaching the vision. For example, the currently available battery cells are not small or powerful enough to satisfy both capacity and volume requirements.
This has lead to the creation of this roadmap, where the logical and required innovation steps are identified to evolve from Bayck 1 towards the vision.

From Bayck 1 to D3
Smaller battery, split up into two to make it a usable object detached from bike.
USB-C connectors on battery to connect to recent phones and laptops.

From D3 to D1
Develop own control box, smaller because less features than current c-b. Batteries and c-b to the front docking.
Wireless PAS on pedal shaft

From D1 to Bayck VISION
Incorporating smaller cells but equivalent capacity, reduce battery from 2 to 1. Include boost/step down converter to match lower voltage devices. Include the control-box in the external package.

PROGRAM OF REQUIREMENTS

The Program of Requirements is set-up following Pugh's checklist described in the Delft Design Guide. The requirements are deducted from the insights gained in the analysis, the concept definition and existing Bayck requirements.

T.b.d stands for To Be Determined, meaning being out of scope of the duration of this project and needs to be determined by the client in a later stadium of the design process.

Product: complete e-bike, including the support device.
Support device: PAS + docking + 2 batteries + control box + motor.
Battery: combination of two 18V 4.4 Ah batteries.

1. Performance
What main functions does the product need to fulfil?

1.1 The battery should withstand a minimum range of 15 km in urban conditions, at an average of 20km/h.
1.2 The support device should assist pedalling up to 25km/h.
1.3 The bike must be usable when the batteries are flat.
1.4 The support device must assist up to 250W.
1.5 A front lamp must be included in the product, powered by the battery.

2. Environment
What kind of environmental influences does the product need to withstand during use?

2.1 The support device withstands IPX0 up to IPX4 (splash water in any direction) in waterproof tests.
2.2 The product must be operational from -10 up to 40 degrees.
2.3 The product should not dismount due to the vibrations of cycling.

3. Life in service
With what intensity will the product be used and how long should it last?

3.1 The product must be usable daily (recharge rate battery)
3.3 The battery must fulfil 1.1 for a minimum time span of 5 years

4. Maintenance
Is maintenance necessary and possible? What part need to be accessible?

4.1 Maintenance or replacement of hardware on the product to normal use must completely possible by the user.
4.2 The support device needs to be removable from the bike without destruction.

5. Target product cost
What is a realistic price for the product, considering similar products?

5.1 The price of the product should be less expensive than the less expensive version of Back 1: 1199.- (retail price).

6. Transport
What requirements are set by transport of the product during production and the location of usage?

T.b.d.

7. Packaging
Is packaging needed? Against what should the packaging protect?

T.b.d.

8. Quantity
What is the amount of units to be produced?

8.1 A first production batch of 1000 complete products will be made.

9. Production facilities
Should the product be designed for existing production facilities, or is it possible to invest in new production resources. Outsourcing of production?

9.1 The frame of Bayck 1 is used with altered production steps. The new frame is produced in the same facility as the Bayck 1 frame (China).
9.2 The production and assembly of the internal parts of the battery is outsourced to a third party company (Greenway China is currently the battery supplier).
9.3 Resources must be invested for the production of the control box, battery casing and docking station, outsourced to third party companies.
9.4 Existing hardware (lamps, tires, brakes, ...) are ordered from a third party supplier and assembled in the Netherlands

10. Size and weight
Are there boundaries to the size and weight of the product due to production, transport or use?

10.1 The volume of a single battery should not exceed 0.6L
10.2 The mass of the complete product should be equal or less than Bayck 1: [25:28] kg.

11. Aesthetic, appearance and finish
Which preferences do buyers and users have? Should the product fit a house style?

11.1 The aesthetics of the product should be recognisable from mood-board 2, integrating signature Bayck aesthetics and use clues visible in mood-board 1.

12. Materials
Should certain materials (not) be used?

12.1 Durable materials must be favoured to prevent damage or undesired wear during normal use.
12.2 Materials must be selected based on their stiffness and strength to meet requirement 2.3.
12.3 Used materials should fit the style set in mood-board 2

13. Product life span
How long is the product expected to be produced and sold?

13.1 The product is expected to be produced and sold until the next step in the roadmap is achieved, meaning 5 to 10 years.

14. Standards, rules and regulations
What standards rules or regulations apply to the product and the production process?

14.1 The support device must stop at the speed of 25km/h
14.2 The support device must be regulated by the PAS, no user throttle is allowed.

15. Ergonomics
What requirements result from observing, understanding, handling, operating, ..., the product?

15.1 The battery should have visual indicators to help install them on the bike.
15.2 The shape of the battery must prevent the battery installed wrongly
15.3 The support device must be usable without a smartphone
15.4 The battery must indicate its state of charge
15.5 A battery must be attachable/detachable requiring a single hand.

16. Reliability
What chances of failure is acceptable?

T.b.d.

17. Storage
Are there long periods of storing time during production, distribution or usage of the product?

17.1 The assembled batteries must be stored fully charged, for a maximum duration of 12 months until recharge to prevent complete discharge.

18. Testing
What quality tests are conducted on the product?

18.1 Short-circuit test
18.2 Over-charge test
18.3 Over-discharge test
18.4 High-temperature test
18.5 Low-temperature test
These tests are to be performed by the battery manufacturer.

19. Safety
Should specific precautions be taken with regards to the safety of users and non users?

19.1 The support device should not hamper the activity of cycling
19.2 The support device should not distract the user while cycling.
19.3 The user should not be able to access the electrical pins of the battery with its fingers.
19.4 The voltage and amperage must clearly be indicated on the surface of the device to inform the user.

20. Product policy
Are there requirements resulting from the company's current product portfolio?

T.b.d.

21. Societal and political implications
What opinions are there currently in society concerning these products?

T.b.d.

22: Product liability
For what kinds of design, production or usage can the producer be held accountable?

T.b.d.

23: Installation and initiation of use
What requirements result from assembly outside the factory, installation, connecting to the other systems and learning how to handle and operate the product?

23.1 The product must be mounted and ready for use at delivery.
23.2 A user manual must be provided with the product.

24: Reuse, recycling
Can the material cycle be extended by reuse of parts and materials? Are parts and materials easy to separate for recycling or waste processing?

24.1 The elements forming the support device must be removable and replaceable individually as modules in case of failure or obsolescence.
24.2 The casing and the cells of the battery must be separable, the user must be able to change the cells but reuse the casing.
24.3 Bayck must sell the components of the support device separately to empower the user to change individual parts in case of failure.

-Design-

DELIVER

MATERIALISATION

The materialisation of the concept is done following the fish trapping method, the concept definition is making up the basic structure. The structural concept is achieved by identifying all the necessary parts and sub-assemblies. The geometry of the design, the stacking and placing of each component is discussed to form the formal concept. Finally, the production of the resulting parts, assembly, materials, details and aesthetics are discussed to form the material concept; which is the final result of this graduation project.

FISH-TRAP MODEL ACCORDING TO THE DELFT DESIGN GUIDE

Basic structure *The conclusion of the concept defintion: what parts are necessary for the design? Are there sub-assemblies to be integrrated?*

Topological level ↓

Recap of all necessary parts, overview of sub-assemblies to get integrated

Structural concept

Typological level ↓

- *cell stacking*
- *battery placement*
- *component placement*
- *locking mechanism // battery*
- *connection between docking and bike*
- *connection between top and bottom part of docking*

Formal concept

Morphological level ↓

- *fit aesthetic study, mood-boards*
- *manufacturing*
- *material assignment*
- *detailing assembly*
- *textures & colors*

Material concept *End result of this graduation project*

Iterative steps within the fish-trap

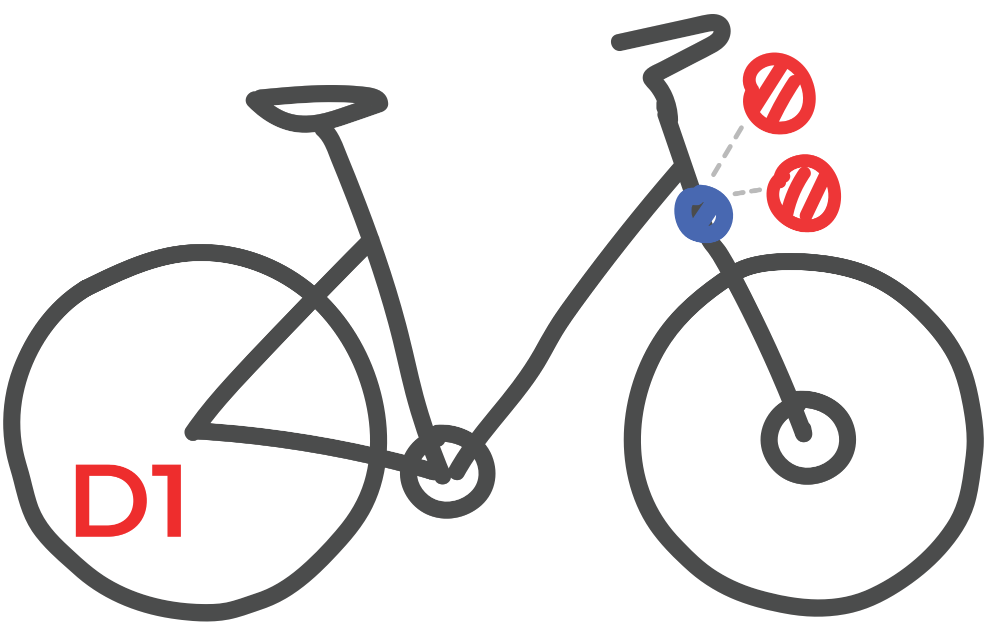
The Fish-trap model is described as a linear model, with a concept evaluation and freeze at the end of each stage. The model is most adequate to be used when the parts to be integrated and criteria for evaluation are defined. As the evaluation criteria were not clear at the start of the materialisation phase, it was not possible to conclude and move on to the next phase without the need for adjustment later on. In order to identify the assessment criteria, the steps until a material concepts are performed multiple times in a fast track. These resulting material concepts are key for the final concept.

When the necessary criteria were identified, a last concept is made up to the formal concept. to go from formal to material concept for the final design, again multiple iteration steps are taken to conclude the design.

TOPOLOGICAL STUDY (FROM BASIC STRUCTURE TO STRUCTURAL CONCEPT)

This drawing is the basic structure from which we start in order to formulate the structural concept.
Up to this point, we have decided that the elements necessary for the functioning of the e-bike will be moved to the front, as close as possible to the motor, yet accessible by the user.

The sensor becomes wireless and remains near the pedals. The control box remains on the bike while both 18V batteries can be taken off.
At this point, we identify that the control-box along with other components need to be confined in a docking. A docking mounted on the front of the bike, unto which the batteries can be plugged-in to make the connection.



A simple Bike, with a docking mounted to the front. The control-box is trapped in de docking (blue). The two 18v batteries are plugged into the docking (red)

Wireless PAS

Multiple wireless paddling sensors are available on the market, most of them are called cadence sensors and are commonly used on racing bikes. These systems are often removable.
There are mainly two kinds of sensors available, the torque sensor and the accelerometer.

The torque meter is not only able to measure if the user is paddling or not but also how much pressure the user puts on the pedals: the torque meter measures material deformation in the crank or shaft.
The crank type sensor is mostly used by fanatic cyclists as the sensor is very expensive (> €200 consumer price).
Budget shaft sensors are available from €40 consumer price.

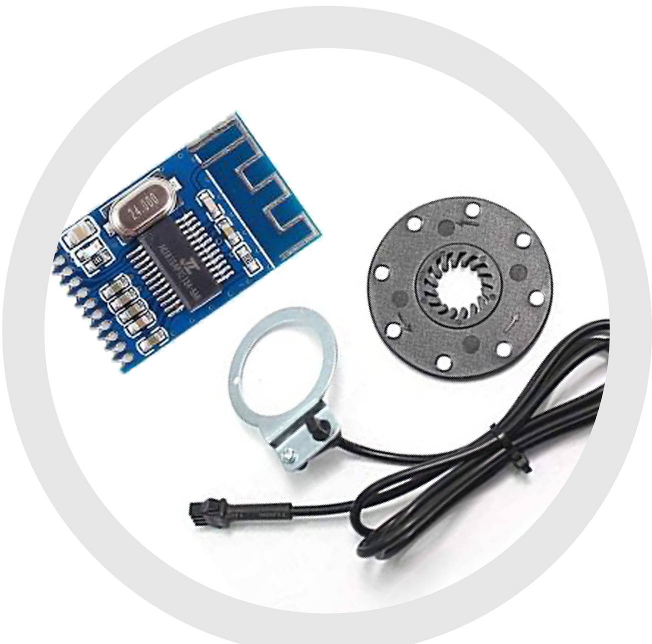
The accelerometer measures the vibration or sudden direction changes (acceleration) through piezoelectricity. The accelerometer must be attached on the crank near the pedal in order for it to sense the acceleration. Most current available accelerometers are attached with flexible rubber bands in order for them to be removed easily. Budget cadence meters cost around €40 consumer price (Garmin, Wahoo).

Finally, the already used magnet sensor on Bayck 1 is by far less expensive (budget models at €8 consumer price). These magnet sensors do not yet exist in a wireless configuration.
Blue-tooth modules are simple to use and inexpensive as well (€5).
Producing an inexpensive and unique wireless PAS is within the resources and ambitions of the company.
Finally, magnet sensors are known to be robust and are fixed between the crank and frame, which makes it impossible to steal without removing the crank.

Comment: due to the precision of the torque sensors or accelerometers, the reactivity of the control box is quicker and smoother. The control box can also be programmed to deliver power depending on the amount of user input, instead of going full on and off without gradient such as the magnet sensor.
A more expensive but more adaptive solution could be adopted in a future iteration for more user comfort.

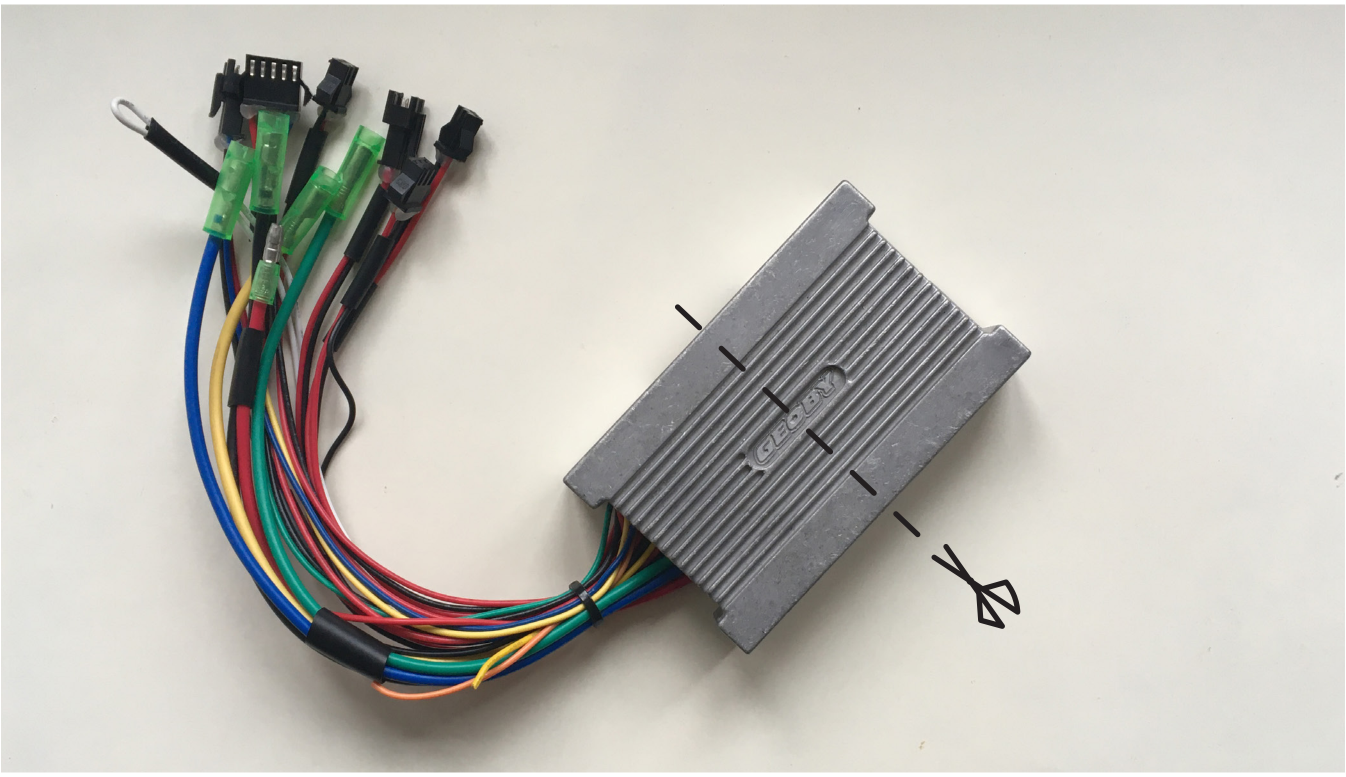
4iii Torque meter

Wahoo Accelerometer



Magnet sensor + BT

Custom control box

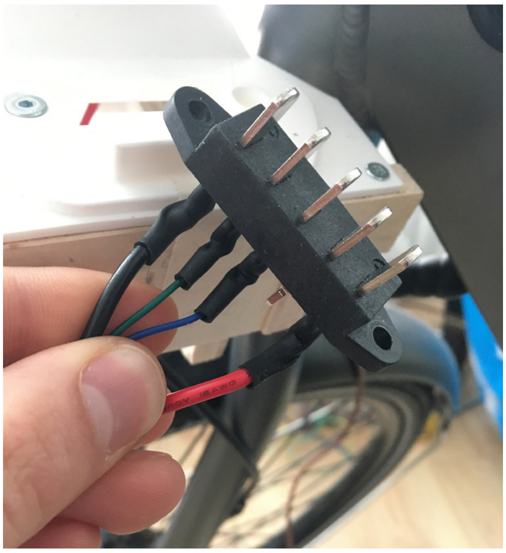


As mentioned before, features included in the current used CB are not in use, therefore superfluous. The size of the current control box is rather voluminous and includes a rectangular casing.
To reduce the size of the control box and achieve a better integration in the docking, the client is willing to develop a custom control for the concept.
Based on an educated guess made by the client, the size of the control can be reduced by half.

The connections are downed from 7/9 to 4: motor connection, Bluetooth module for PAS data reception, battery connection and lamp powering. The current dimensions of the control box are roughly 100x60x20 mm, the new dimension of the control box are 50x60x20mm. The electronics will be protected in an air-tight seal inside the docking to protect it from dust and water, although the seal is not permanent and the device can be disassembled and repaired.

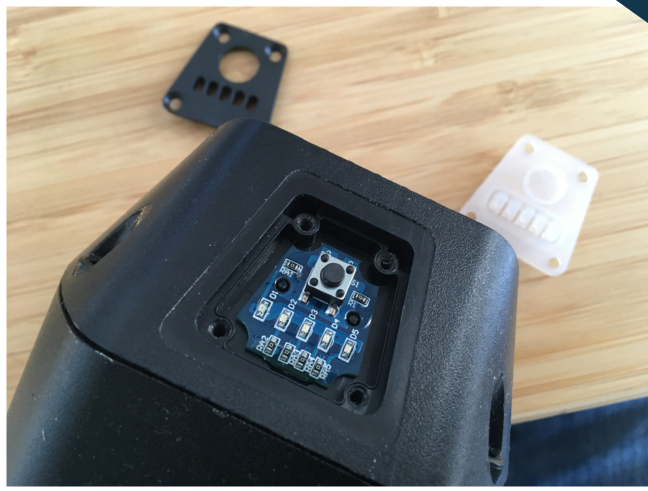
5-pin connector

Even though only 4 pins are in use, Bayck currently uses a 5 pin connector to connect the battery. This is because the supplier (Greenway) mostly produces 5-pin connector batteries and are therefore logically cheaper than connectors with less pins.
The two outside pins are the positive and negative pole, two other pins are for data transmission and data receive; data such as temperature, battery status, etc...
The same male and female connectors are taken for the new design.



Status LED

on the current Bayck battery, the charge status of the battery is indicated by a small led-strip on the top of the battery; a little knob activates the led's. The same technique is translated to the new design.



Cells and BMS

The same 18650 cells are used for this new design, simply because they are the cheapest and largely available on the market.
The size of the BMS relates to the voltage that it is adapted to (it influences the amount of necessary mosfet's and connection ports). The two 18V BMS have a rough box dimension of 60mm x 80mm x 10mm.

USB-C PD connector

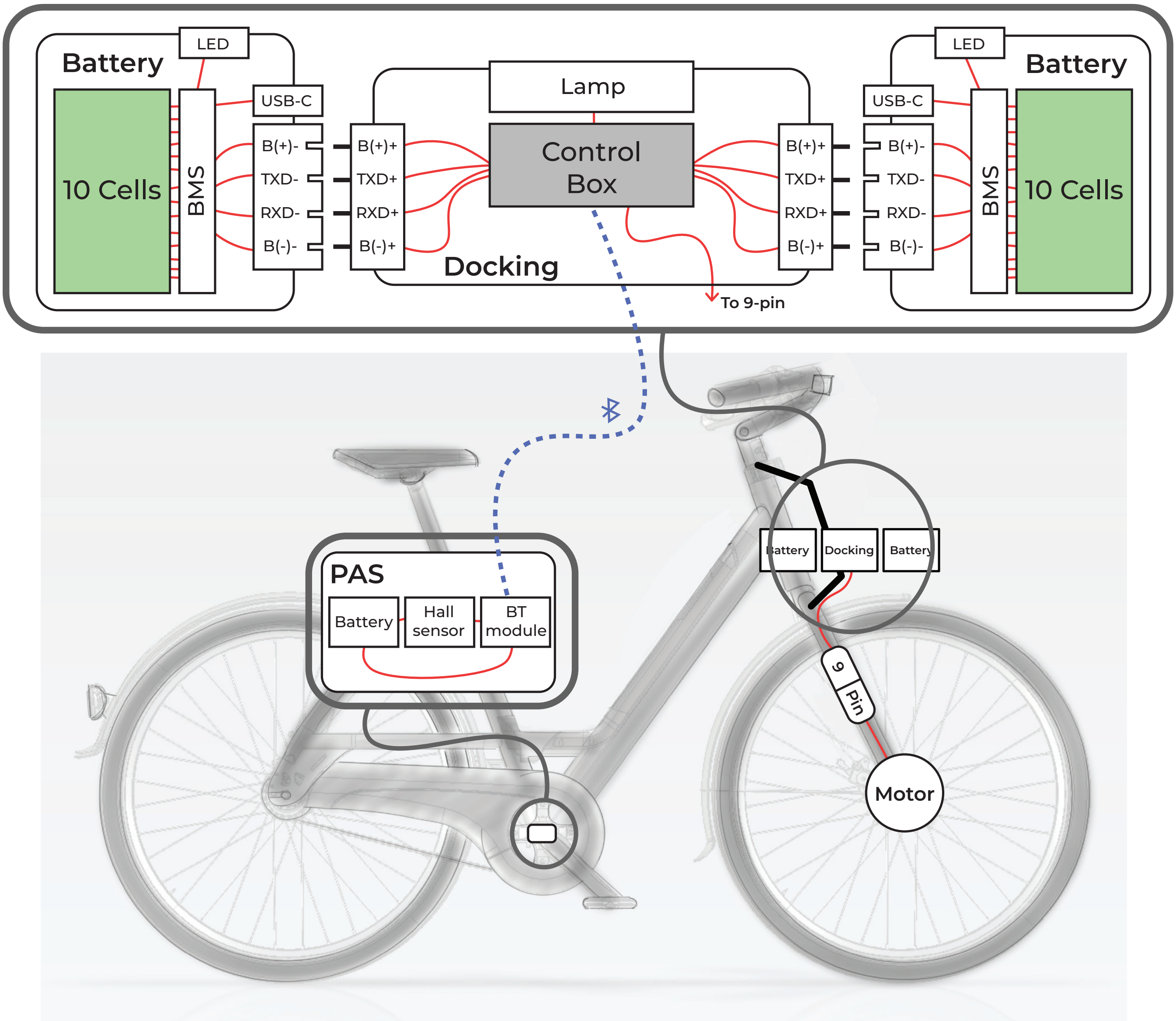
The USB-C PD port is used for charging the battery or deliver power to external devices. The Port is connected the BMS in both batteries. The connector has a box dimension of 16mm x 10mm x 4mm.

Front Lamp

A front lamp is connected to the control box, and is turned on as soon as both batteries are connected. The lamp consists of led's in a casing which will be integrated in the design of the battery docking.
Bayck orders the lamps they sell on their bikes at Spanninga, which is a Dutch lamp manufacturer. For the sake of this project, the lamp will be designed to fit the overall aesthetics of the product at best, instead of taking an existing Spanninga model.

CONNECTION SCHEMATIC

An overview of all components identified so far and their connections can been seen below.
As the method of mechanical connection between the batteries and the docking is not yet clear, a lock or release buttons are not yet included in the system.
The 9-pin connector between the control box and hub-motor are not taken into consideration for a redesign and are reused from Bayck 1.



DESK DOCKING STATION?

The idea about a desk docking station for charging is brought into discussion multiple times during the project.
Since the device can be charged with a regular USB-C charger, designing a desk docking station is not necessary, and conflicts with the design vision of reducing as much as we can. Therefore no desk docking station will be designed.
If the user needs to charge both batteries at once, it can use a USB adapter with a dual outlet and a second cable.

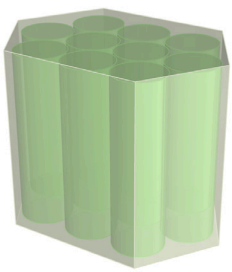
This schematic marks the end of the typological study and freezes the structural concept.

TOPOLOGICAL STUDY (FROM STRUCTURAL CONCEPT TO FORMAL CONCEPT)

CELL STACKING

The components of the battery are stacked in multiple ways to seek for the smallest volume.

The battery contains 10 cells (contained in a plastic holder), the BMS, 5-pin female connector, the USB-C port, status LED and wiring.
Since the cells are the most voluminous parts and define the geometry of the battery, the shape of the battery is defined based upon the stacking of the cells.



Stack #0

Volume: 0.40 L

Box dimensions:
95 x 65 x 78 mm

Stack #3

Volume: 0.44 L

Box dimensions:
115 x 50 x 78 mm

Stack #1

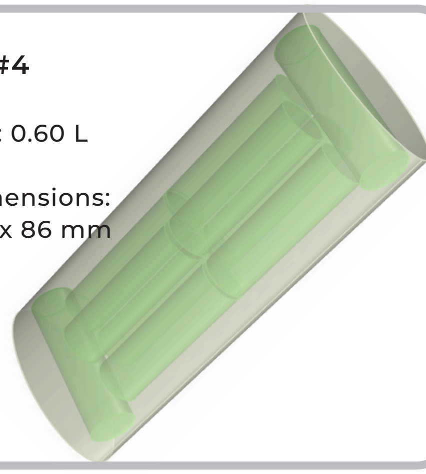
Volume: 0.43 L

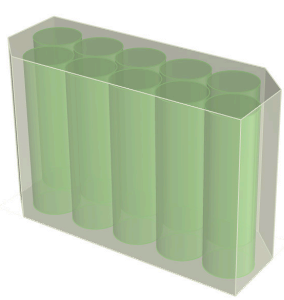
Box dimensions:
152 x 45 x 76 mm

Stack #4

Volume: 0.60 L

Box dimensions:
197x 46 x 86 mm





Stack #2

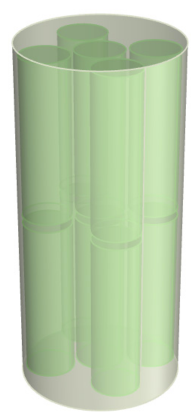
Volume: 0.40 L

Box dimensions:
145 x 45 x 78 mm

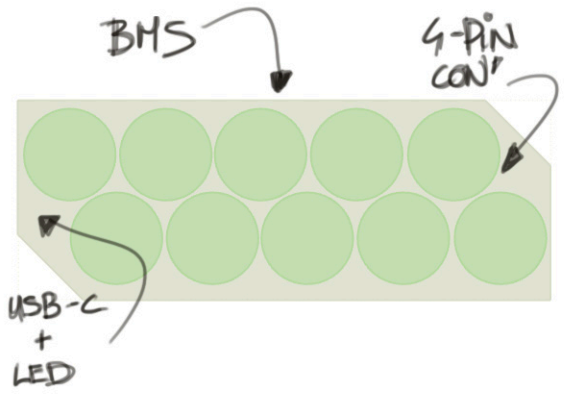
Stack #5

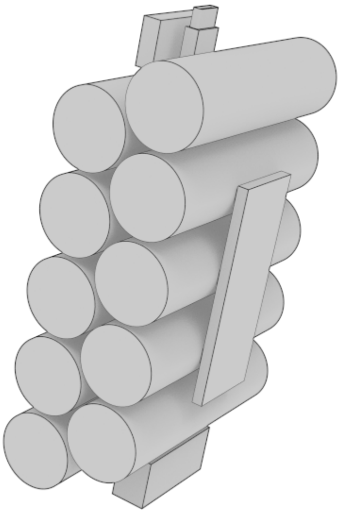
Volume: 0.57 L

Box dimensions:
152 x 69 x 69 mm

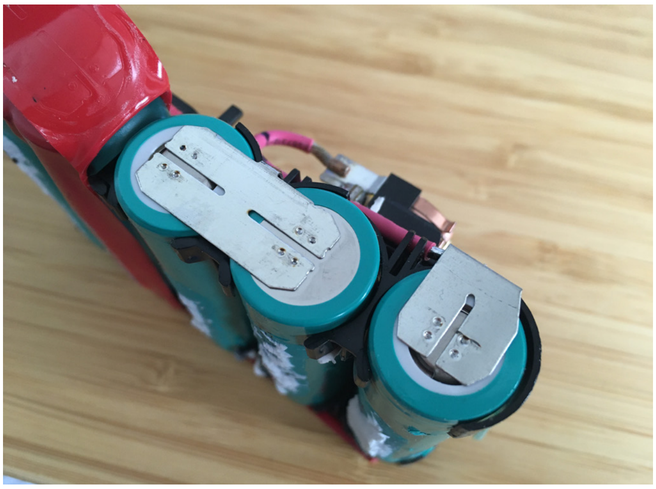


Stack #0 is the configuration used for the current Bayck 1 battery, with 4 stacks on top of each other.
Stack #0 and stack #2 have the same volume.
As identified in the storyboard, the battery is used on the bike but must also be a stand-alone product which could stand on a desk at home, or office. The user will surely carry the batteries around in its pockets or bag. Therefore, it is decided that the slimmer rectangular shape will fit the use best.

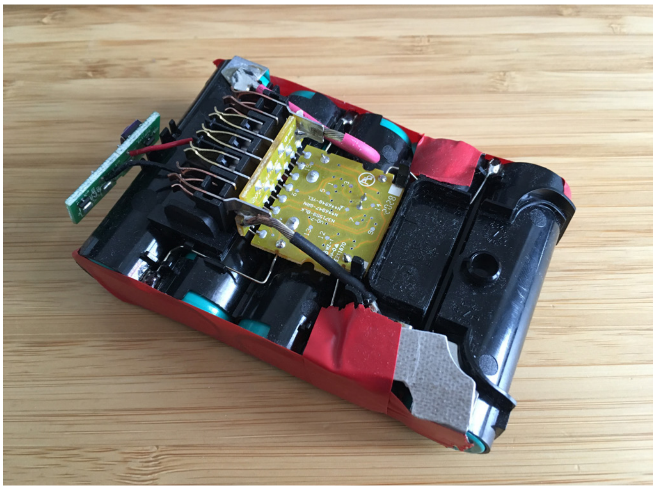




The BMS is add on the flat side of stack
The USB-C and female connector re placed on opposite sides: the user can now use the USB port while biking. The status led is placed next to the USB port.
Enough clearance is left between the cells for cell holder and wires.
The Inconvenience of an angle between the cells makes it harder to weld the nickel strips to the terminals, but this is the case for stack #2 as well as stack #0.

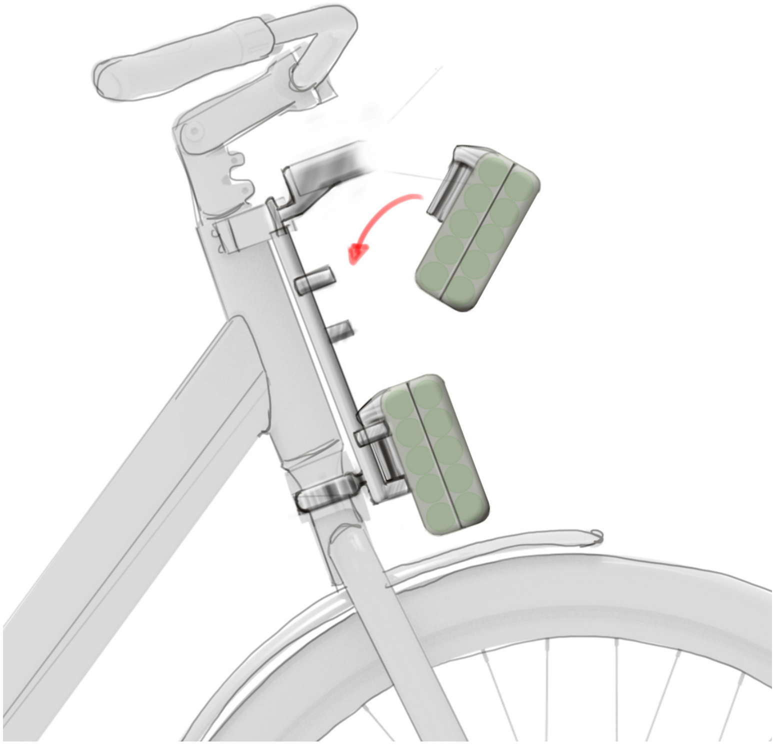


On this picture, you see the point welded nickel strips which connect the terminals of the batteries. A straight cell pattern makes it easier to connect the cells.

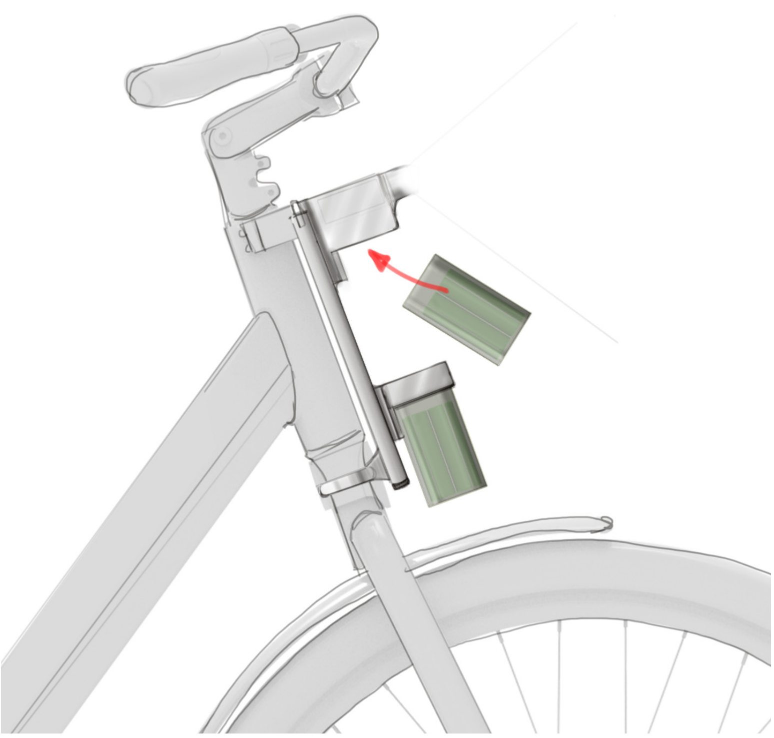


On this picture, you see 5 cells contained in a plastic holder which insulates and protects the cells.
This package is taken out of a DeWalt battery for study and will be used in the functional prototype.

CONNECTING THE BATTERY



Connection mechanism within the battery



Most of the mechanism within the docking

Connect, or get connected?

In order to connect the battery to the holder, there should be a connection mechanism.
A choice must be made between how much of the mechanism is integrated in the battery and how much in the battery holder. For example, most power tool batteries have a prominent slider plus release button adding up to a relatively big battery volume. On the flip side, it leaves almost nothing on the tool itself. Whereas if we look at the first console memory cards or game cartridges, the whole mechanism is integrated in the console, leaving only a tiny dent or ridge on the cartridge.

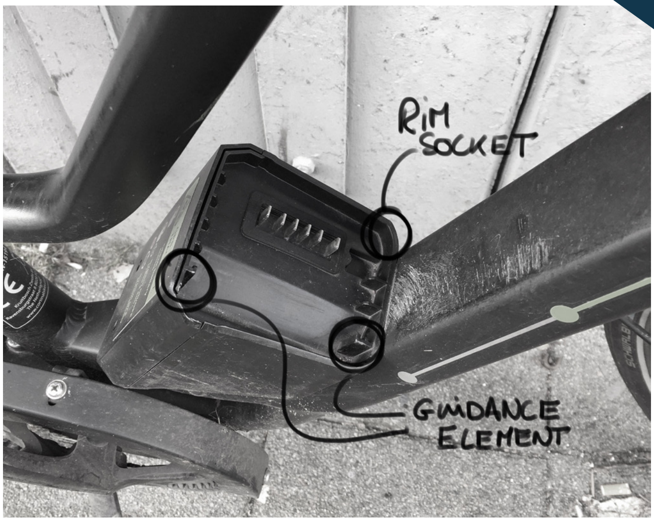
Since it is the intention to use the battery as a stand-alone product besides being the battery of the bike, the mechanism elements on the battery should be eliminated as much as possible and 1§ on the docking.

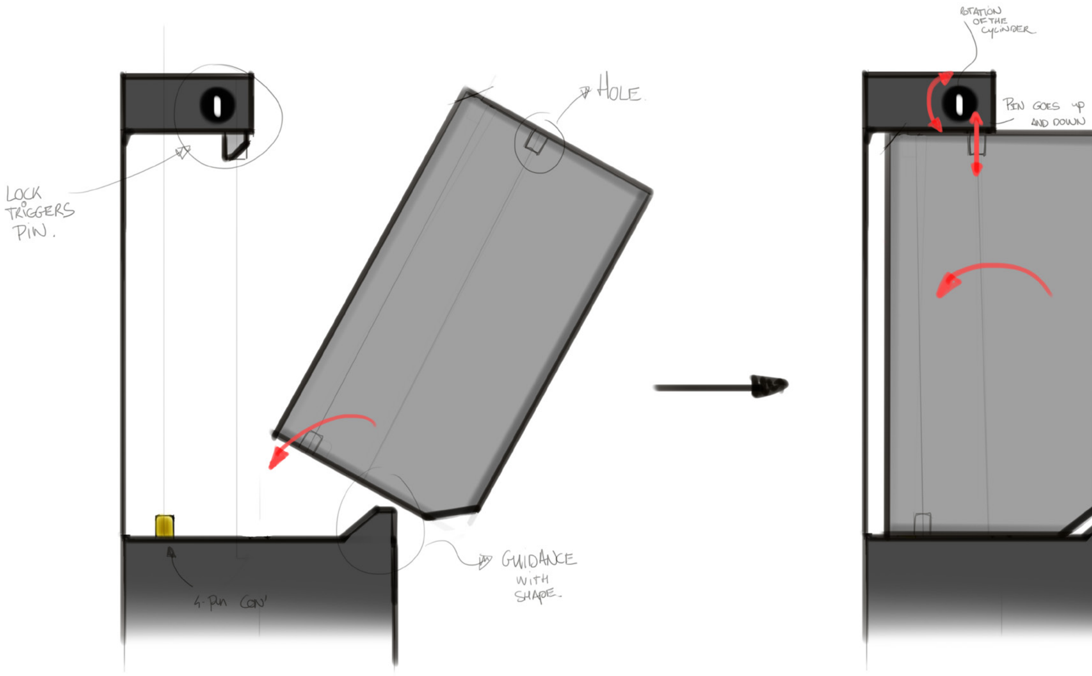
Makita Battery

Super Nintendo game cartridge

Tilt and Click

The first identified mechanism is the one currently used on Bayck 1 and other E-bikes systems. The bottom of the battery is placed in the holder to connect the pins, then the battery is tilted inwards to lift up the locking pin until the locking pin finds its socket. Most of the time, the locking pin is connected to a cylindrical lock, which releases the pin when turned.

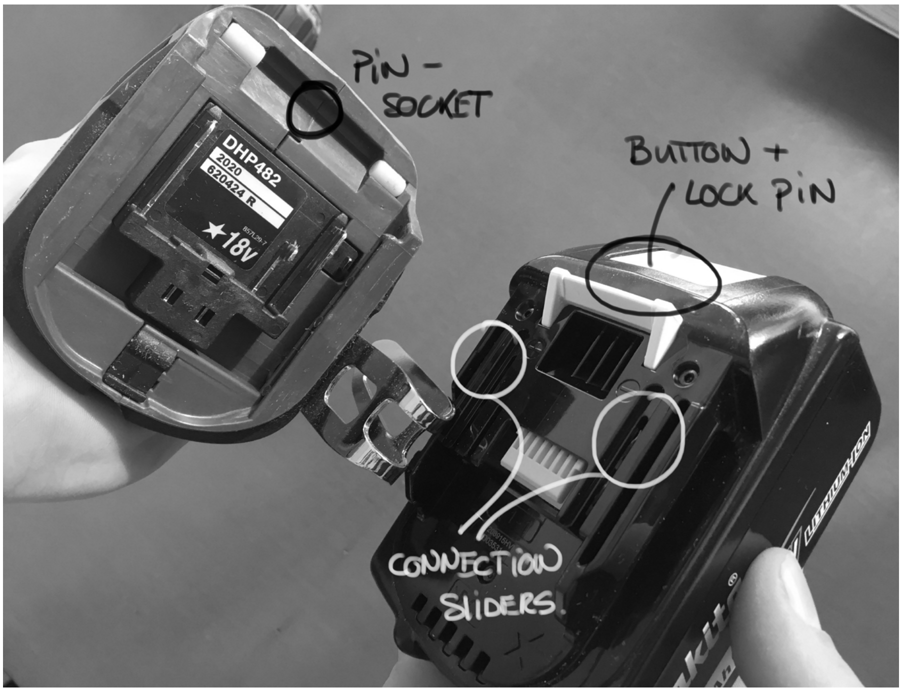


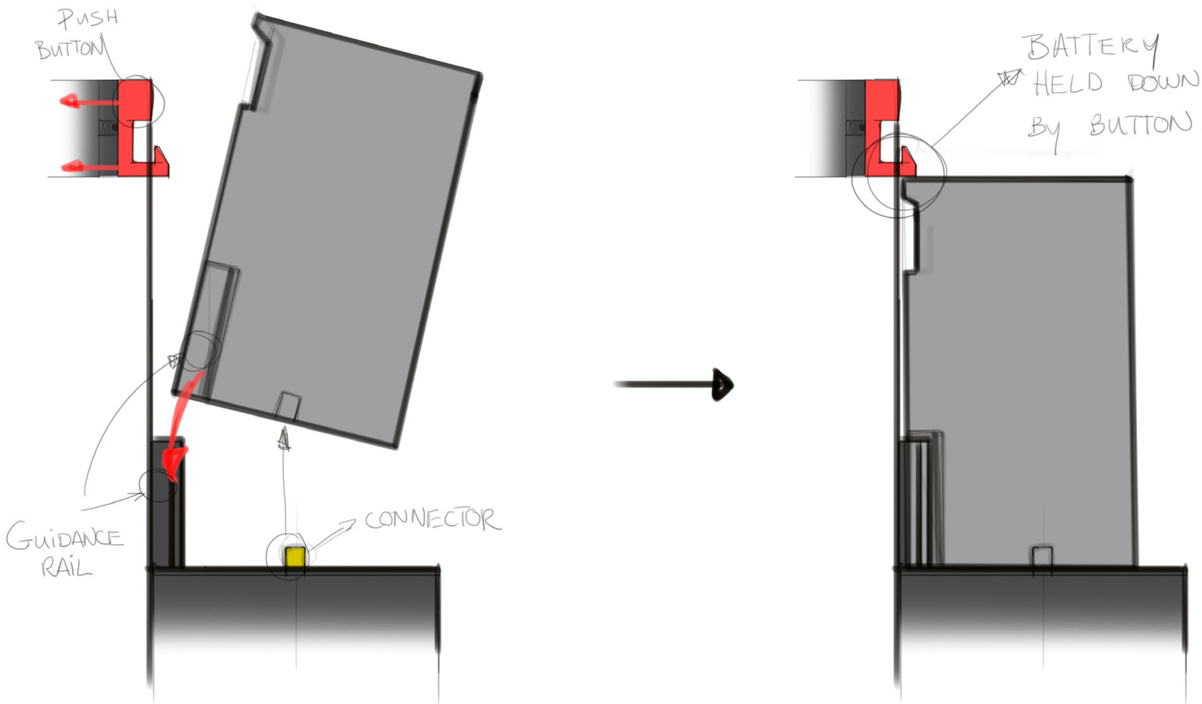


This mechanism requires the connective pins to be parallel the axle of tilt, otherwise the pins get stuck or might break. This means that the batteries need to be inserted from the sides with this mechanism.

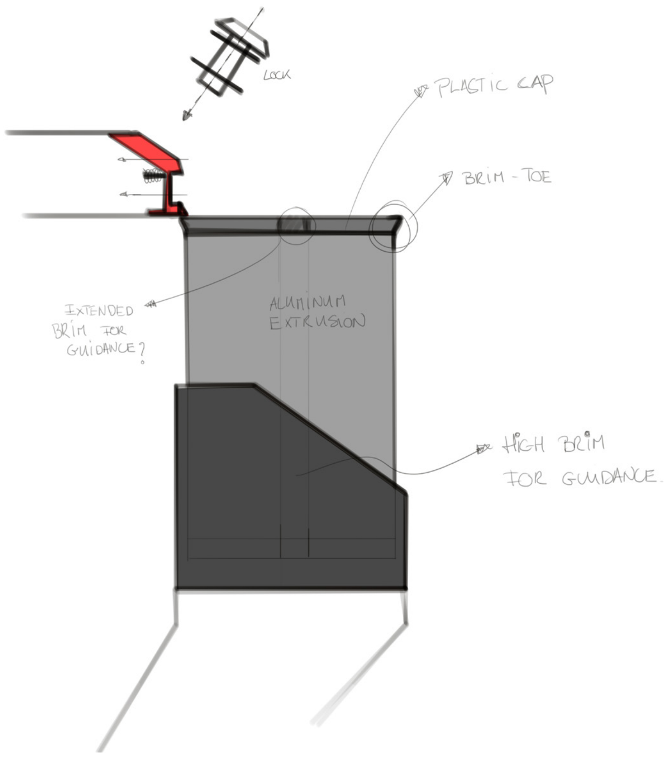
Slide and Click

The second explored mechanism is the one used on power tools.
The motion of connection in this case is linear: The battery slides down until the pins are connected and the locking pin found its socket. Most of the time, the locking pin is actioned by a push button, which releases the battery when pushed in.





The battery is slid in from the top; this mechanism requires a guidance rail, guiding the battery down until the button clamps it in. The button can be combined to a lock, which hampers the button to be pushed in when locked. A higher brim which guides the battery down is an alternative solution to a guidance rail. In the first design proposal, we use this mechanism in combination with a lock and a high brim instead of a rail.



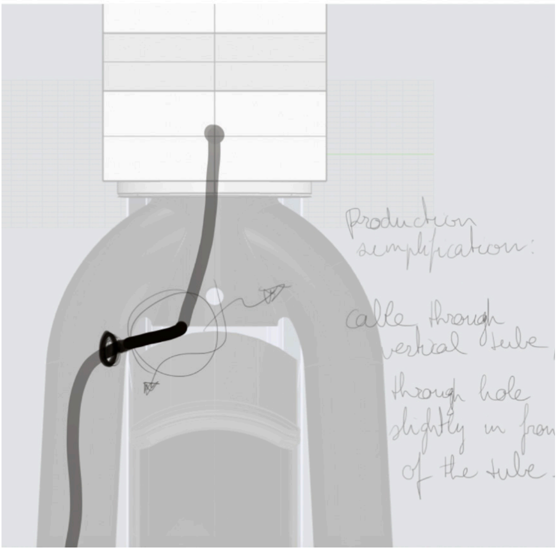
in the current Bayck design, it is only possible to remove the battery by a twist of the key. It would be convenient to be able to release the battery without the necessity of a key, that is why a button is added; the batteries are locked only once the lock is turned.
The lock is placed at the top of the battery, angled to save some space. When locked, it is not possible to push in the buttons. The brim of the battery's edges are angled
Additional structural sliders could be added at the top so the battery is held at the top as well as at the bottom.

THE LOCK

A different lock than the current used lock on Bayck 1 is required for this mechanism. Shown on the right, it needs to be a lock with a rotational blade which holds the push buttons when locked. The rotation blade needs to be modified, as for now it sticks out on one side, it should stick out on both sides.

CABLE MANAGEMENT

As mentioned before, the cable from the control box to the motor could pierce into the fork at the point where the docking is attached to the frame. The cable would come out of the upper tube and pierce again in the right tube of the fork to run down towards the motor. The cable would finally come out at the bottom of the fork to be plugged in the motor. This would complicate the assembly the production process as well as the assembly. This cable management solution is not possible for a retro-fit product. Nonetheless, if this succeeds, no cable would be left to see; This would make the cable less vulnerable. Plus, it would look cool if all the cables are gone.



Battery position relative to headset

The battery is placed relative to the headset of the bike. The two main options are at the front of the headset or on the side. The criteria for selection is based on the vulnerability of the product and accessibility.

Side of headset

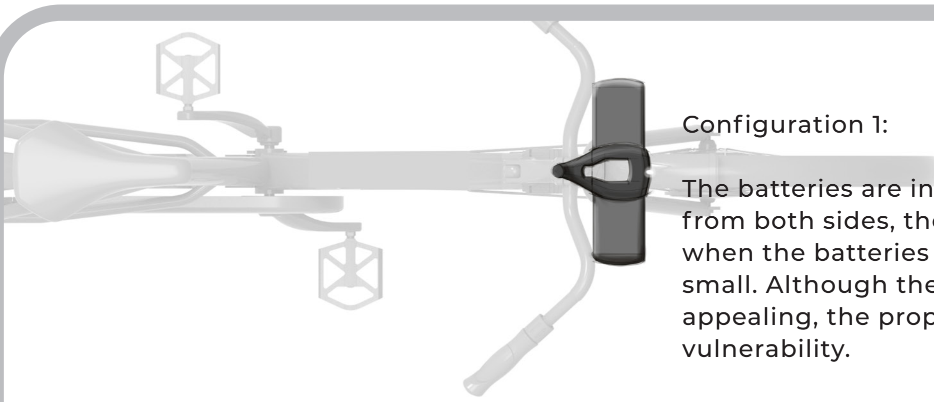
Front of headset

The product would be too vulnerable if it is placed on the side of the headset: The sides of the bike are prone to get entangled when parking a bike in a bike rack, such as at the train-station.

The inconveniences of having the batteries on the front are:
no space for a front-carrier on the bike, blends less with the volumes of the bike/ user; sticks out of the overall volume of the bike + user.

Battery configuration

Multiple battery configurations in front of the headset are explored. The configurations are compared based on their resulting shape and volume. Which configurations is most promising to suit the shapes of the bike?



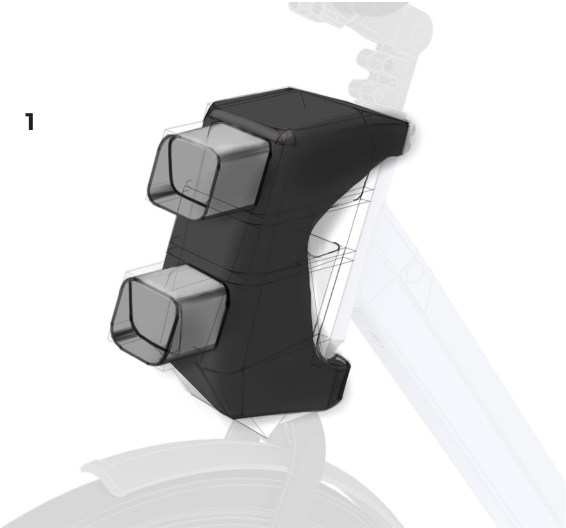
Configuration 1:

The batteries are inserted into the bracket from both sides, the remaining bracket when the batteries are taken away is quite small. Although the shape is aesthetically appealing, the proposal is discarded due to its vulnerability.

Configuration 2:

The batteries are inserted from the side one above each other. The remaining bracket is voluminous and asymmetric, which is less desirable.

1



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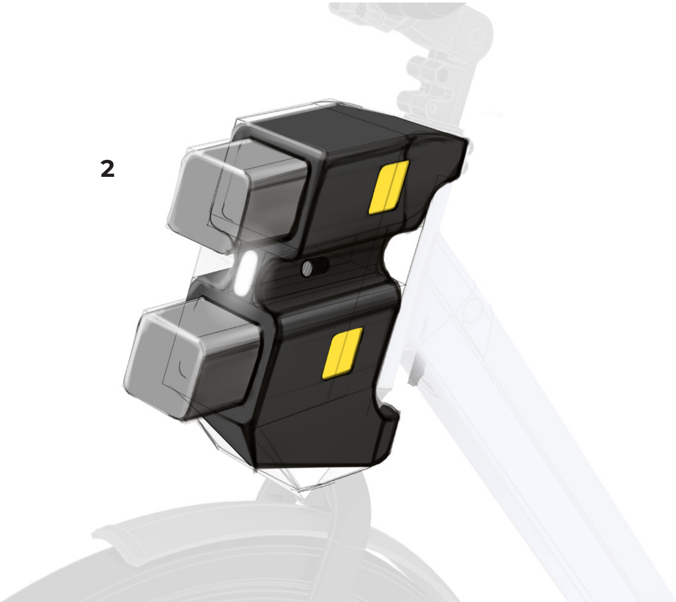

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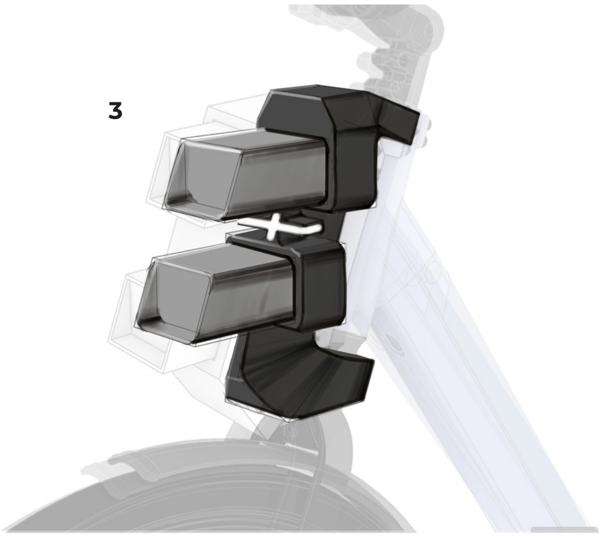
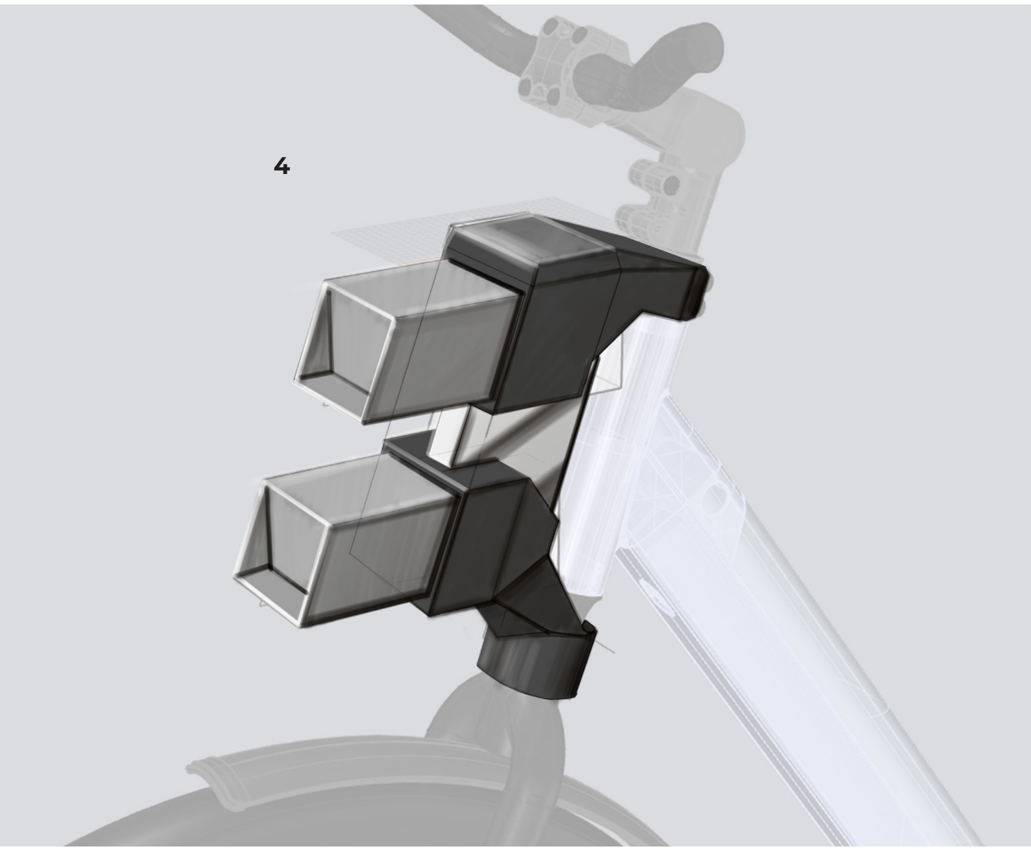
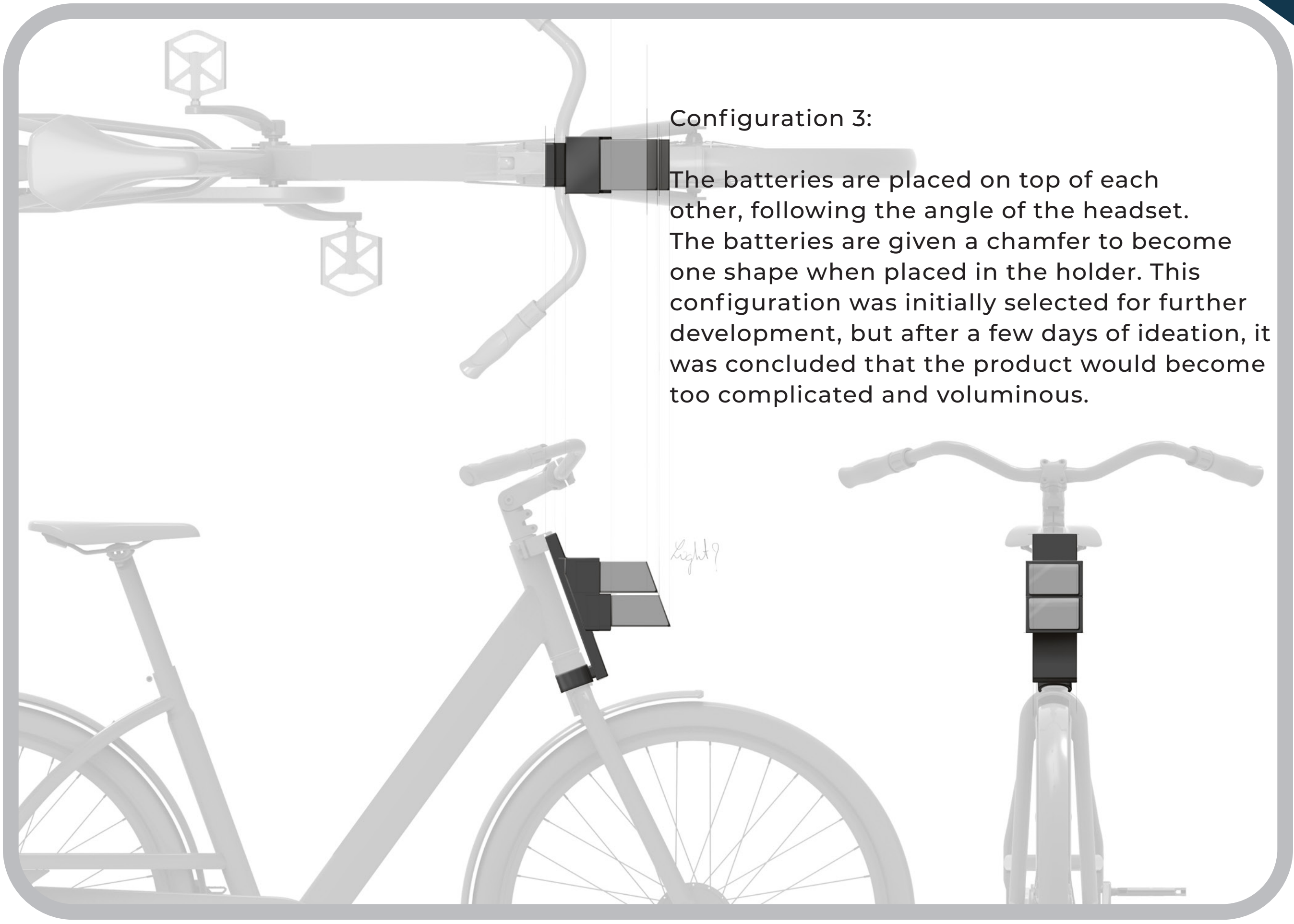


The configuration has little unity, with a complex structure and little ensemble.
This configuration yields no satisfactory result and therefore more configurations are made. Some interesting elements are identified through this ideation nonetheless: The two battery holder are connected to a central "spine" which is the central structural element of the design (seen in drawing 4)

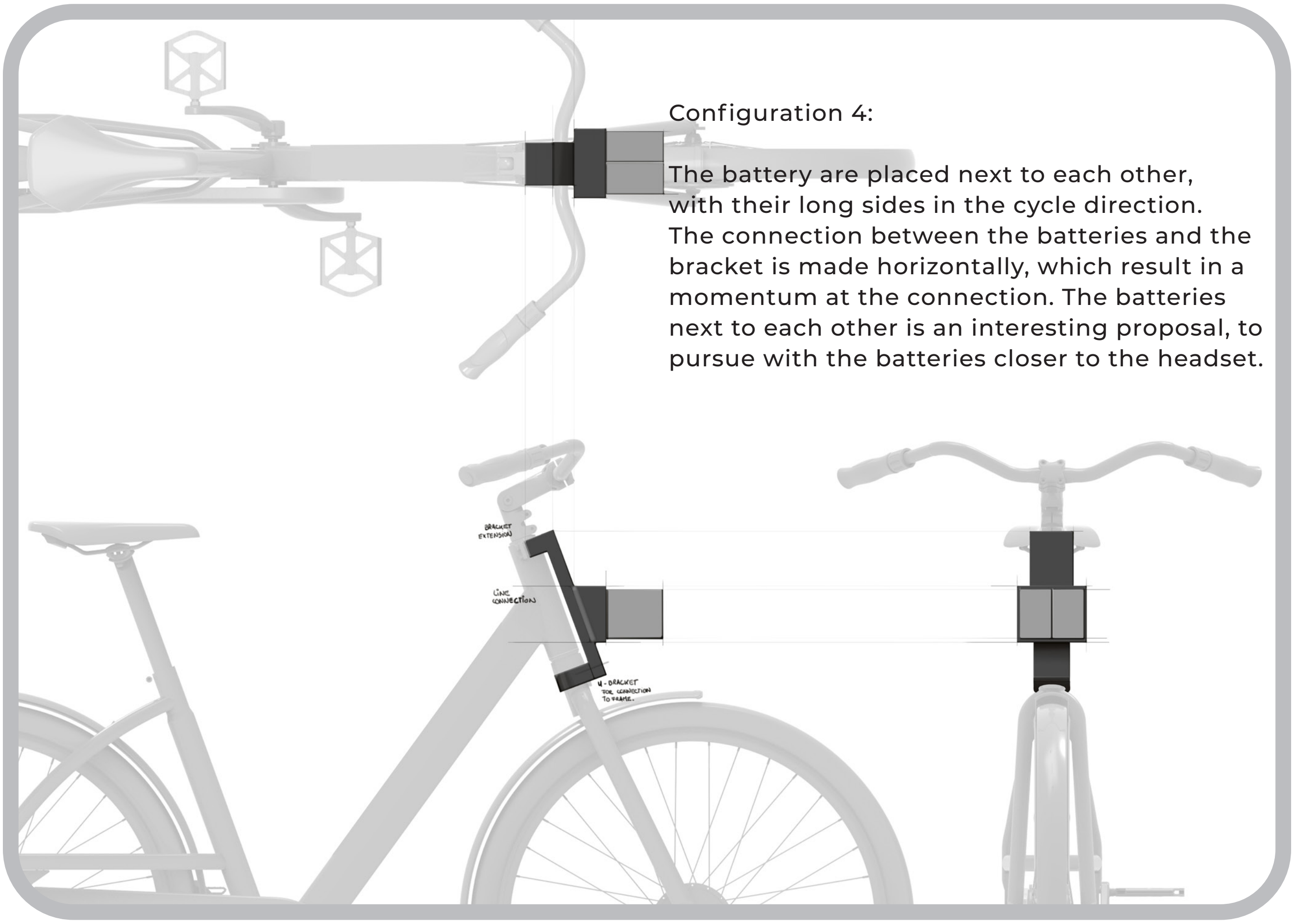
4





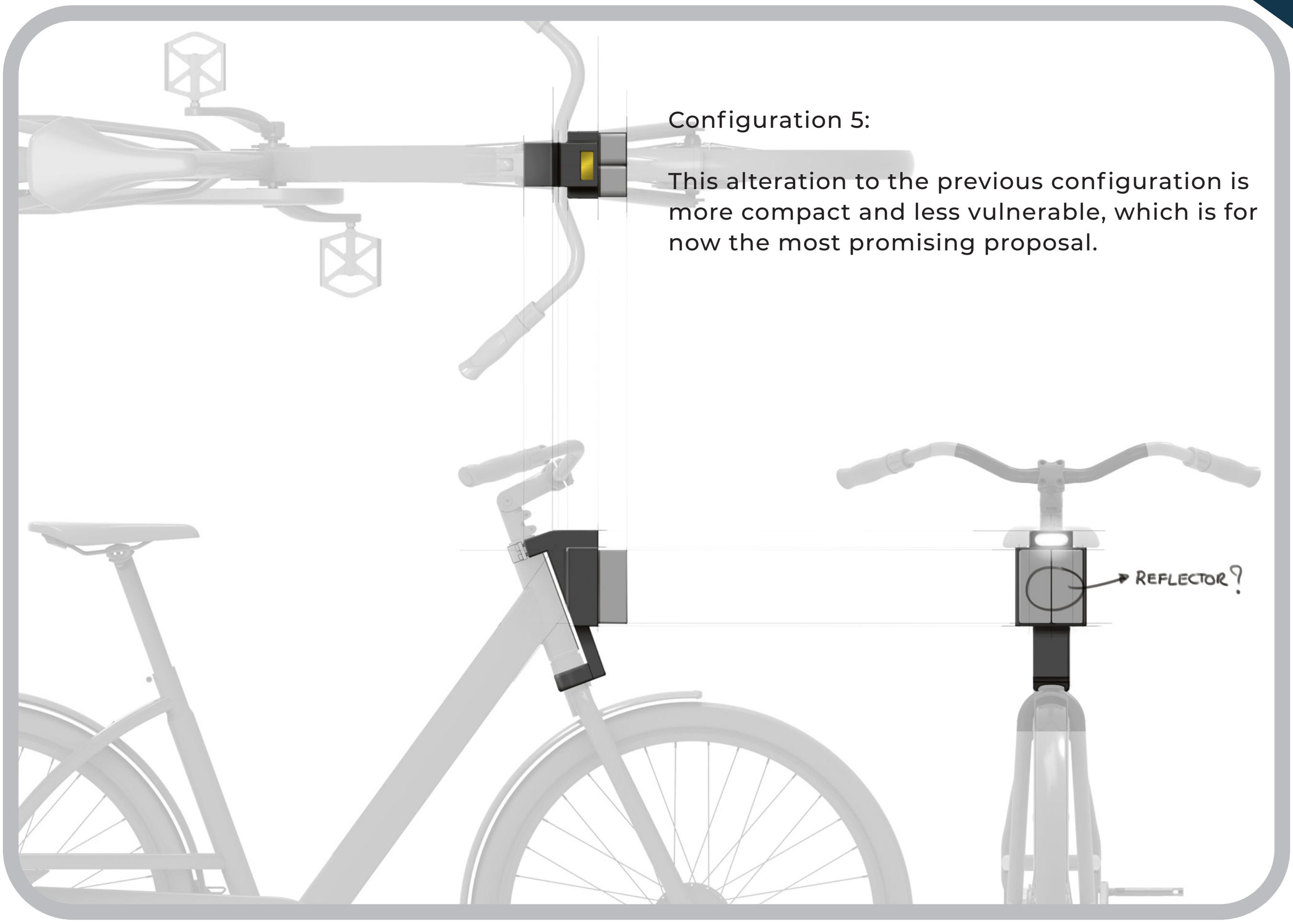
Configuration 3:

The batteries are placed on top of each other, following the angle of the headset. The batteries are given a chamfer to become one shape when placed in the holder. This configuration was initially selected for further development, but after a few days of ideation, it was concluded that the product would become too complicated and voluminous.



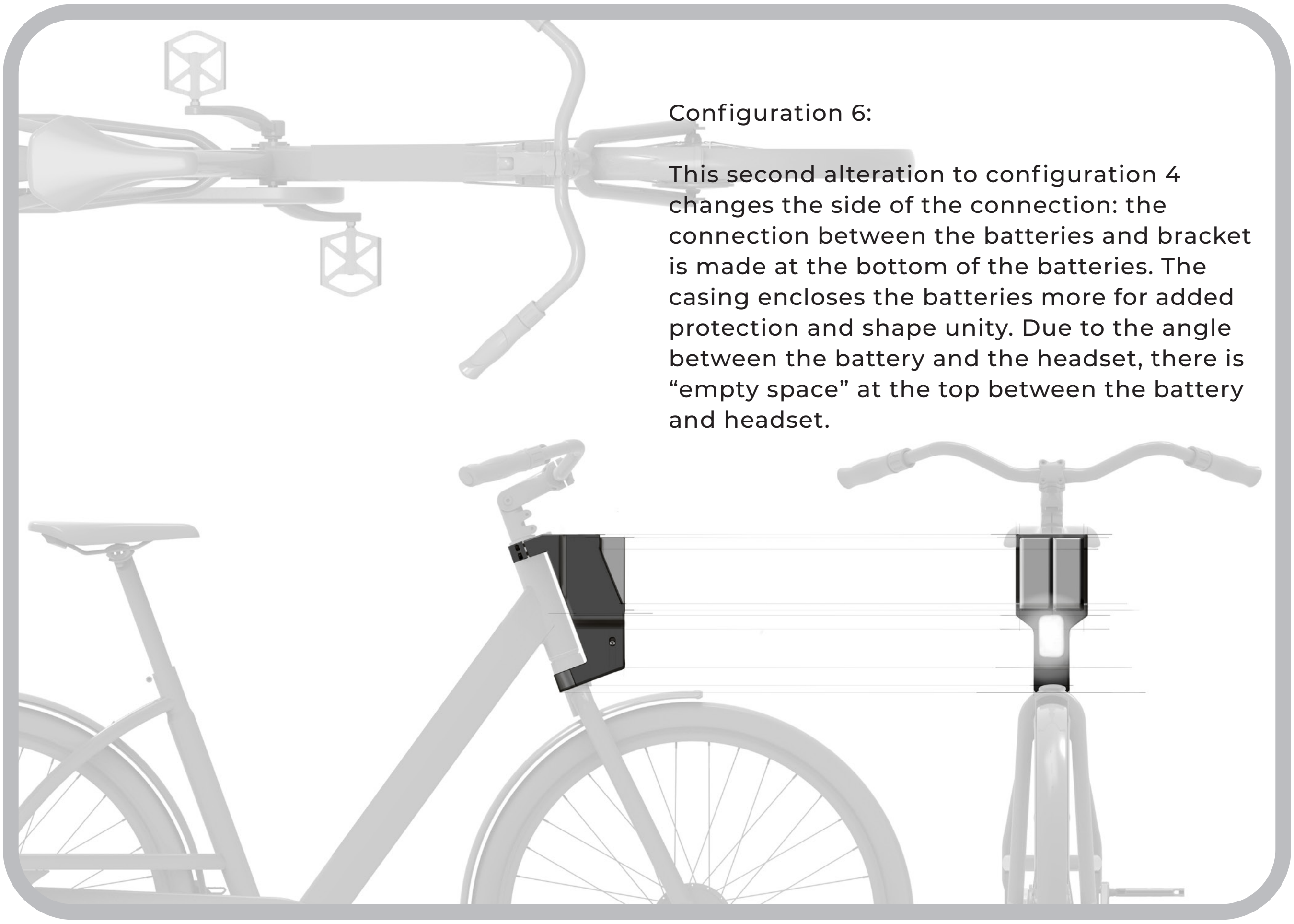
Configuration 4:

The battery are placed next to each other, with their long sides in the cycle direction. The connection between the batteries and the bracket is made horizontally, which result in a momentum at the connection. The batteries next to each other is an interesting proposal, to pursue with the batteries closer to the headset.



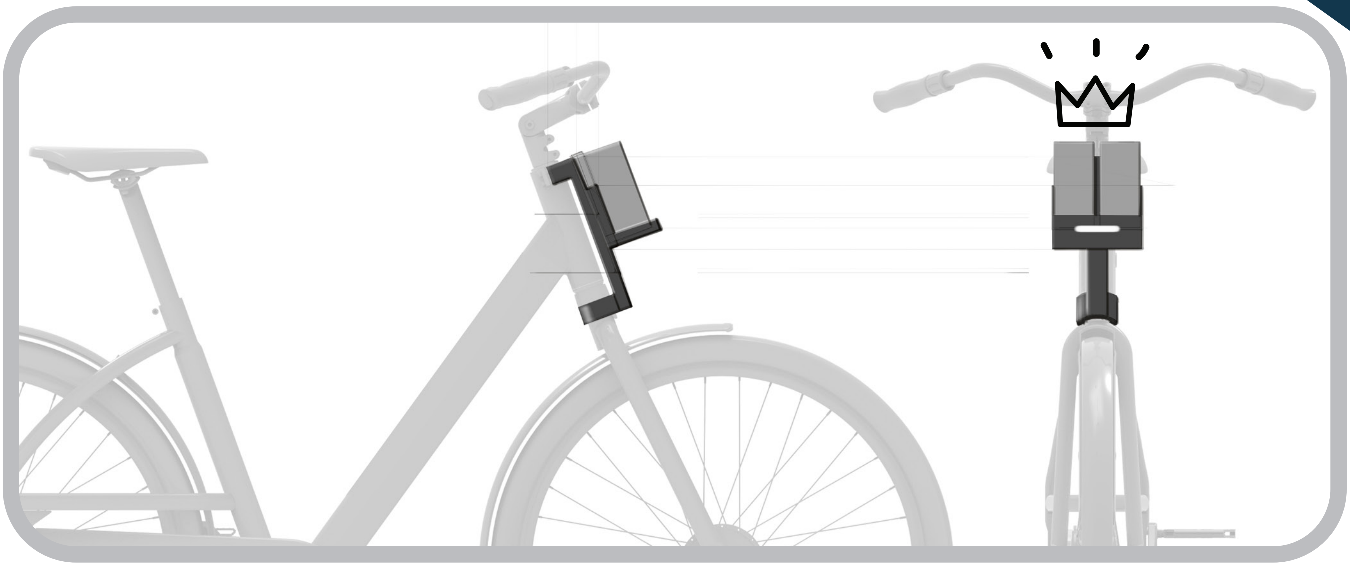
Configuration 5:

This alteration to the previous configuration is more compact and less vulnerable, which is for now the most promising proposal.



Configuration 6:

This second alteration to configuration 4 changes the side of the connection: the connection between the batteries and bracket is made at the bottom of the batteries. The casing encloses the batteries more for added protection and shape unity. Due to the angle between the battery and the headset, there is “empty space” at the top between the battery and headset.



Configuration 7:

This final configuration is identified as the most promising. Due to the same angle of tilt between the batteries and the headset, the batteries can be placed as close as possible to the headset. The connection between the batteries and the pins is at the bottom of the batteries.

To have a first impression of the real size and volume of the product, a rough model is printed and placed on the front of a Bayck.

The model used for the print includes realistic battery sizes and enough volume in the docking to hold the male connectors and control box.

FIRST PHYSICAL MODEL

observations

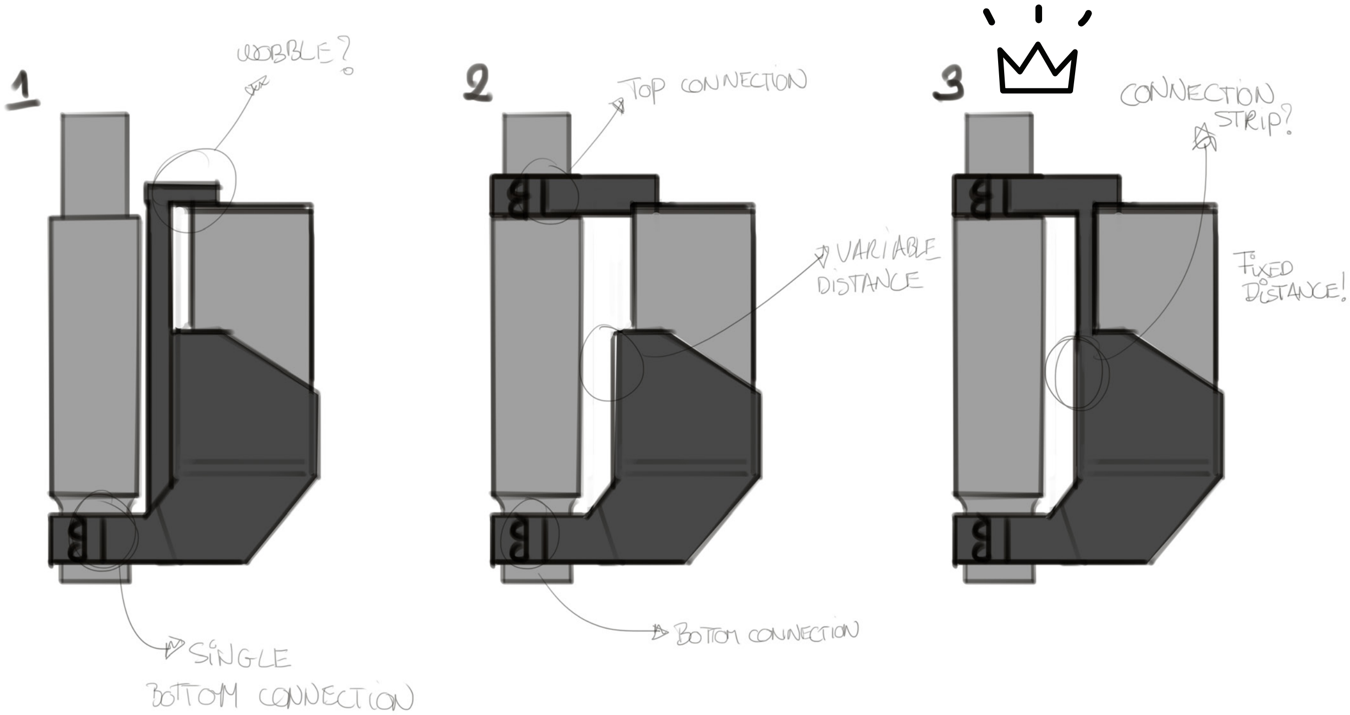
The product as a whole is quite voluminous and thick; it should be kept in mind to restrain the volume as much as possible in order to avoid the product becoming too big.
When the batteries are inserted and the bike is ridden, the batteries start to shake in the docking. In the next step, the batteries will be held from the top as well.
The release buttons and the lock could be placed at the top of the casing to clamp in the batteries from both sides.

The holder clamps around the fork at the bottom of the docking. This is because at this point is discussed if it would be possible to pierce the control-box-to-motor cable through the fork and make it run through the fork to the motor. This would remove all the visible cables from the bike.

The resulting volume of a single battery is satisfactory, here to see next to an Iphone 6 for scale.

CONNECTING THE BATTERY DOCKING TO THE BIKE

In order to attach the connect the docking to the bike, there should be at least a connection point at the bottom, for the motor cable to pierce into the fork.
An aluminium bracket is currently used on Bayck1. The bracket is bolted to an interface in which a front-carrier can be slid.
The steering tube around which this bracket and interface are bolted at has the same diameter as the fork, therefore the bracket can be used on both places. This bracket is used in the new design.
Three different ways to mount the battery holder to the bike are identified below:



1: One point bracket

The battery holder is connected to the bike at the fork. Easy for installation but great moment of inertia at the connection point, most fragile. The device might wobble when riding the bike, which is undesired.

2: Two point bracket, independent

The holder is mounted to the fork and steering with two independent brackets. The top bracket holds the fastening mechanism, the bottom bracket holds the electronics. The two elements are mounted separately, with the possibility of variable distance. This could be interesting in a future scenario in which the device is adaptable to different bikes with different tube-sizes/ headset lengths, but less relevant for this concept.

3: Two point bracket, connected

The holder is mounted to the fork and steering with two brackets, the brackets are connected. This makes the distance fixed between the two brackets. This make the installation of the device easier and less likely to get out of alignment over time (when bumped into).
This set up is selected as the most suitable for this concept.

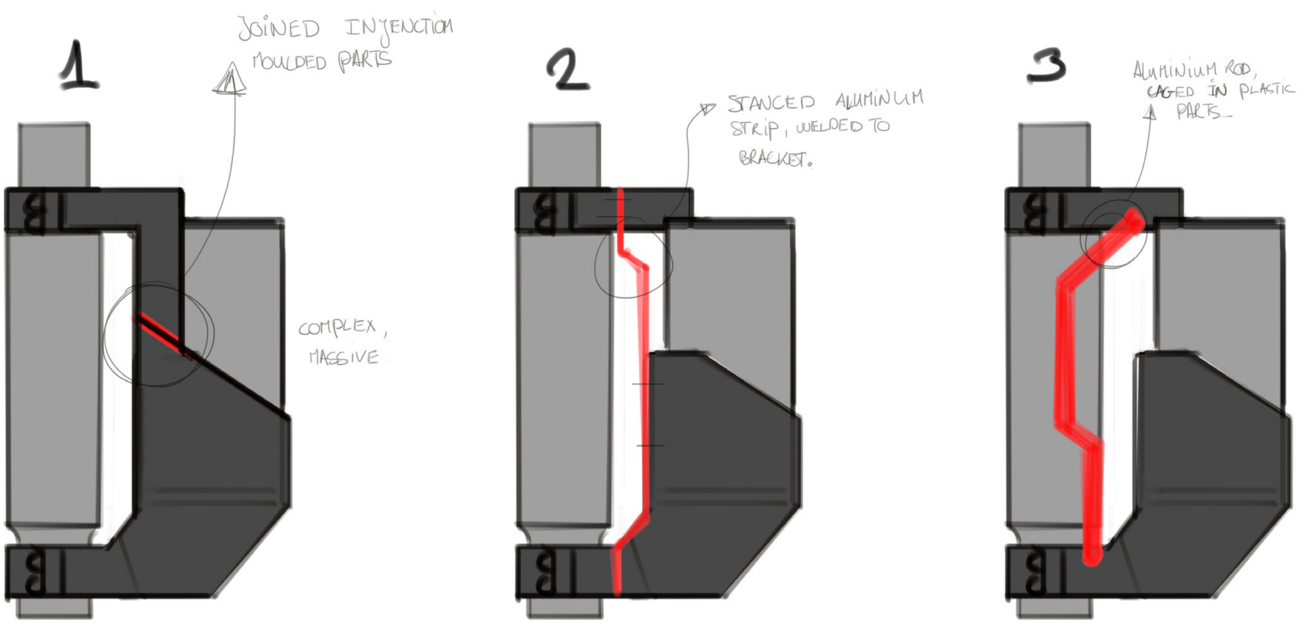
CONNECTING THE TWO BRACKETS

The connection between the brackets can be done multiple ways. The examples: injection moulded parts that blend into each other, a strip functioning as a spine to which the injection moulded parts are mounted unto, or bent rod connecting the two parts.

Bent aluminium rod in combination with injection moulded parts.

Ski bindings are mounted the a connective strip bolted to the skis.

Two injection moulded parts blending into each other.



Option 2 and 3 add considerable stiffness to the structure and reduce the complexity of the injection mould. It is concluded that the construction described in 2 and 3 would perform better over time and are therefore selected.

FIRST PROPOSAL FORMAL CONCEPT

For the first formal concept, the following structure is chosen:

The 2 batteries are built from stack #1.

The batteries are placed in front of the headset, tilted parallel to the headset.

The batteries are placed in the docking with the slide and click technique.

To hold the batteries in place, there is a high brim at the bottom and guiding blades on the top.

The batteries can be released with to separate push buttons, both in relation to a single lock.

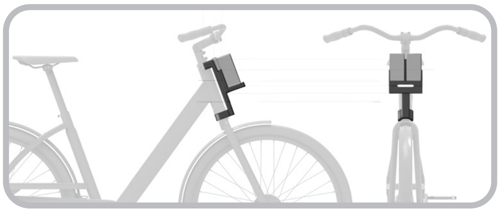
The docking is attached to the frame at the top and bottom with Bayck brackets.

The docking is fixated to a structural plate, which is mounted to both brackets for stiffness.

At this point of the process, the selection criteria that is necessary to freeze the formal concept and move on the material concept is not clear enough. It is decided to move on to the morphological study and build a material concept. The idea is to build a quick material concept in order to find out on what ground we should evaluate the formal concept.

Cell stack

+



Battery position

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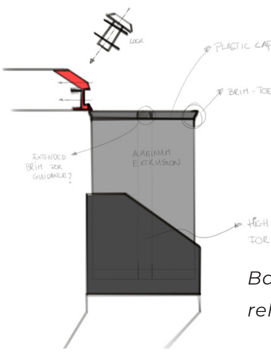

Battery fixation and release

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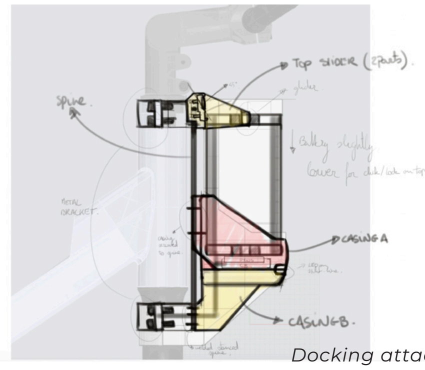

Docking attachment to frame

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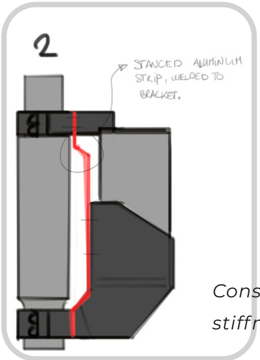
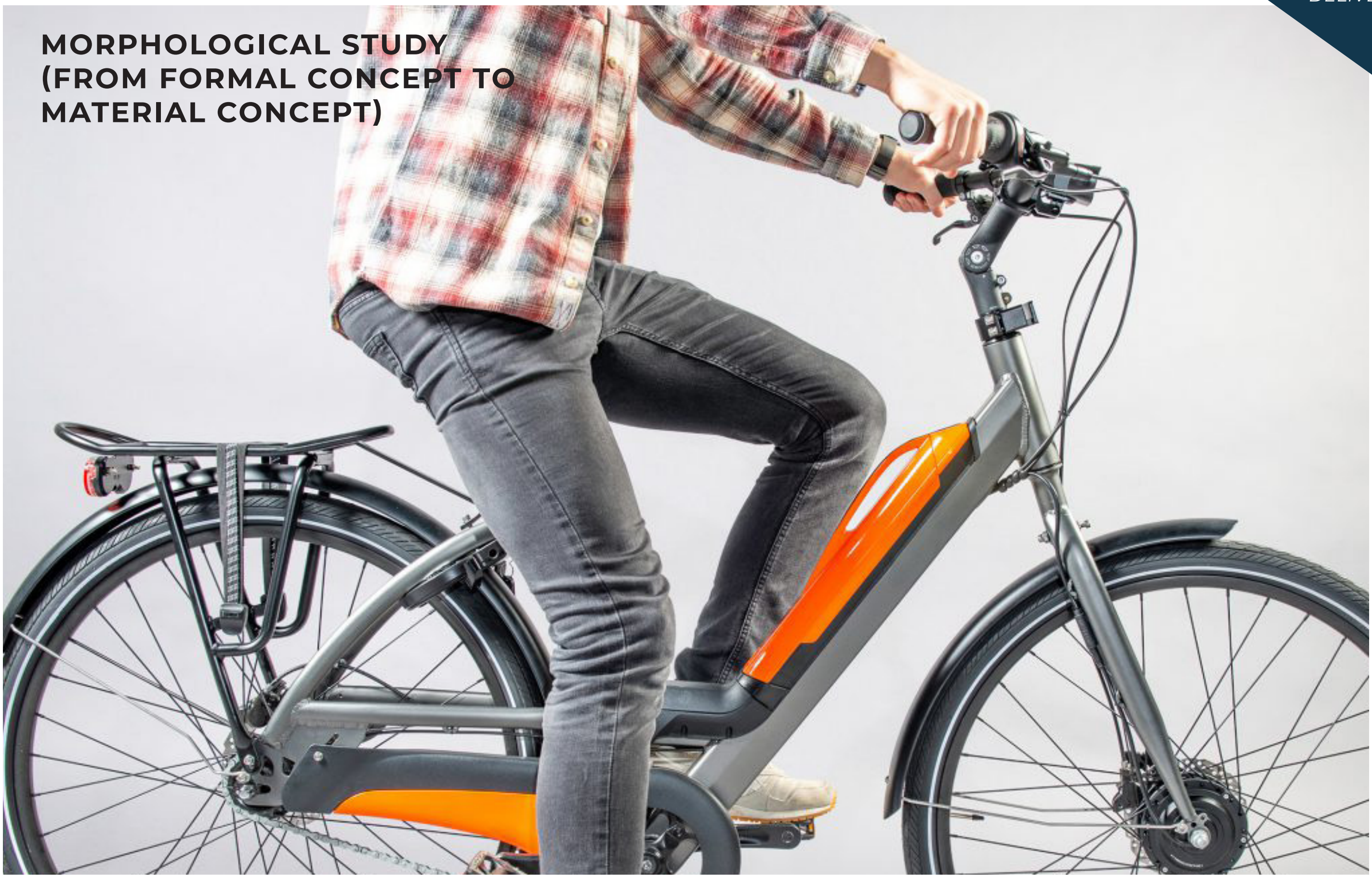


Construction for stiffness.

MORPHOLOGICAL STUDY (FROM FORMAL CONCEPT TO MATERIAL CONCEPT)



BAYCK AESTHETICS STUDY

Geometry

Due to the large trail of the front wheel, the overall shape of the bike is rather lazy.
The upright position of the cyclist due to the high steering and lower saddle makes the bike comfortable and steady. The bike has no top tube, which is characteristic for a "ladies" bike but is largely used for unisex city bikes because of the comfort and convenience of the easy step-on.
The frame is build up from thick tubes; the rear drop-out/hanger is enormous compared to other bikes; both contribute to the chunky look of the design.
The arced seat stay makes the bike look more friendly and open.

Parts and materials

The whole frame is made out of aluminium; the frame combines round tubes as well as a polygonal shaped tube (the down-tube) made through extrusion which adds up to the strong look of the bike. Lately, more and more bikes are made out of aluminium. Aluminium is lighter and allows more shape freedom because it is extrudable and easier to machine overall. Nevertheless, aluminium is way less stiff than steel and therefore frames are considerably bulky compared to steel bikes.
The coloured plastic covers look inexpensive and witty, which contrasts with the anodized finish of the frame.
The combination of aluminium and the coloured shapes attribute an active/sporty look to the bike.

Details

The apparent welding lines, screws, bolts, cables and clear interfaces for carriers or mudguards make the bike look honest and trustworthy.
Most of bikes are mostly recognizable by a signature head/rear-light or frame detail (think of VanMoof, or The Bup), but since all the components such as lights, handlebars, carriers are off -the shelve parts, the bike needs a recognition point somewhere else. This bike is mostly recognizable by the handle on the top of the battery as well the contrast between the dark colour of the frame and the bright and shiny plastic parts covering the battery and the chain-guard.
The on/off button on the handle of the battery adds up to the playfulness of the design.

Aesthetics of design

A first mood-board is made to capture the aesthetics of Bayck1, which should be used as reference for the aesthetics of the battery holder.

MOOD-BOARD 1

This first mood-board captures the aesthetics of Bayck 1.

MOOD-BOARD 2

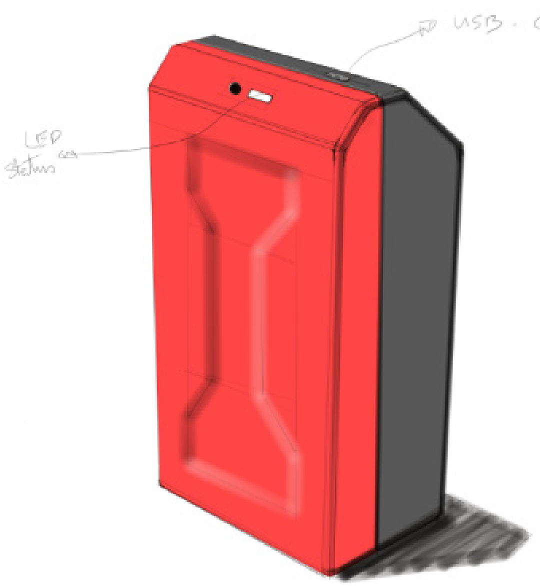
It was decided within the team that the battery should have its own aesthetic language as it would be used on the bike but for other purposes as well. It is as well part of a bike as well as a stand alone product that could stand on the desk of an office or be taken to the park for a picnic (to power a speaker for example).

It was agreed that the battery should have a high quality look and feel, for long-lasting use.
A second mood-board was made capturing honest and high quality aesthetics, which should be used a reference for the design of the battery. The docking station needs to fit the aesthetics of the Bayck as well as the aesthetics of the batteries.

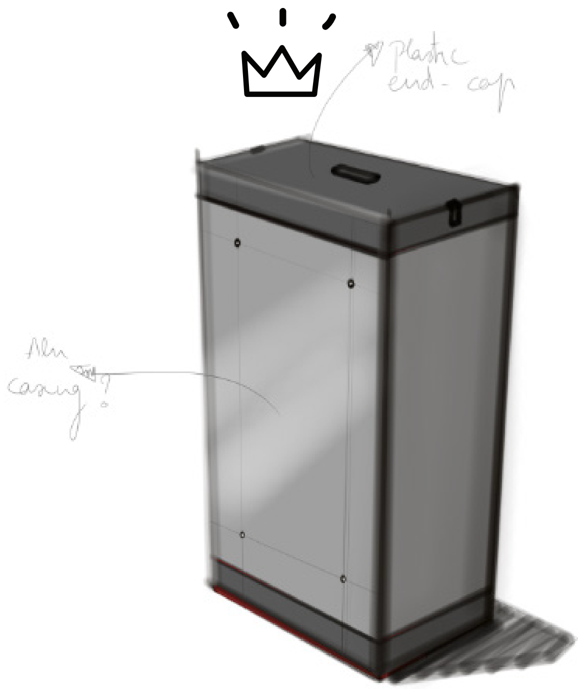
BATTERY CASING

The production technique for the battery casing is determinant for the look and feel of the battery. The two main techniques identified are plastic injection moulding with two parts and aluminium extrusion with plastic end-caps for insulation.
Determine the shape of the whole product first, or is the shape of the battery leading?

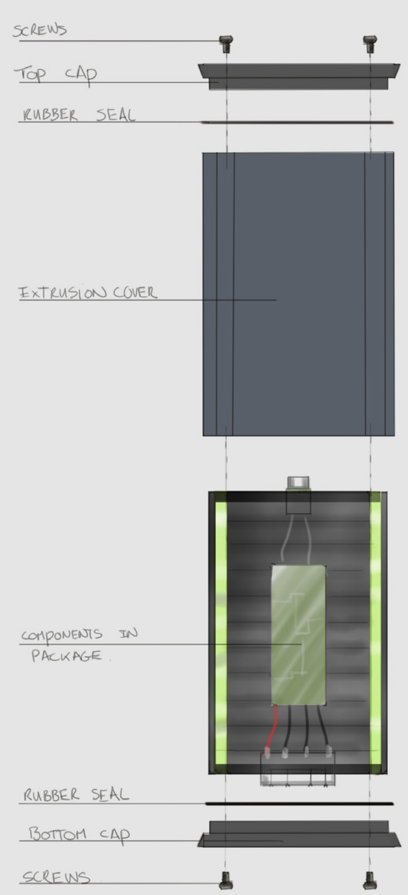
Chapter about form analysis Bayck and conclusion: the battery holder casing blends with moodboard 1, the bike, the battery blends with work environment, desk products: mood-board 2. Aluminium more durable, higher quality.
The connection mechanism is placed on the bracket to limit the volume of the battery as much as possible.



Injection moulded plastic



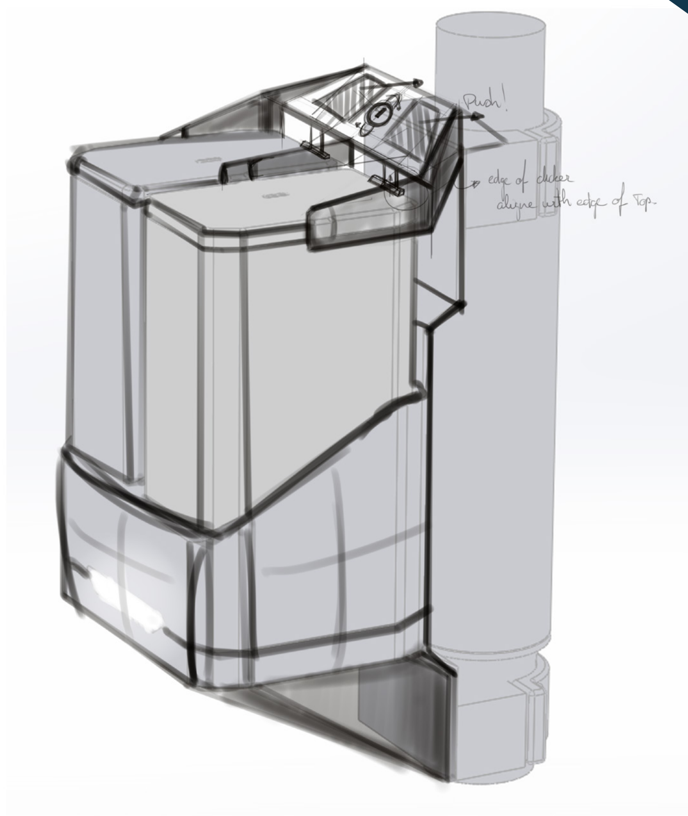
Extruded aluminium

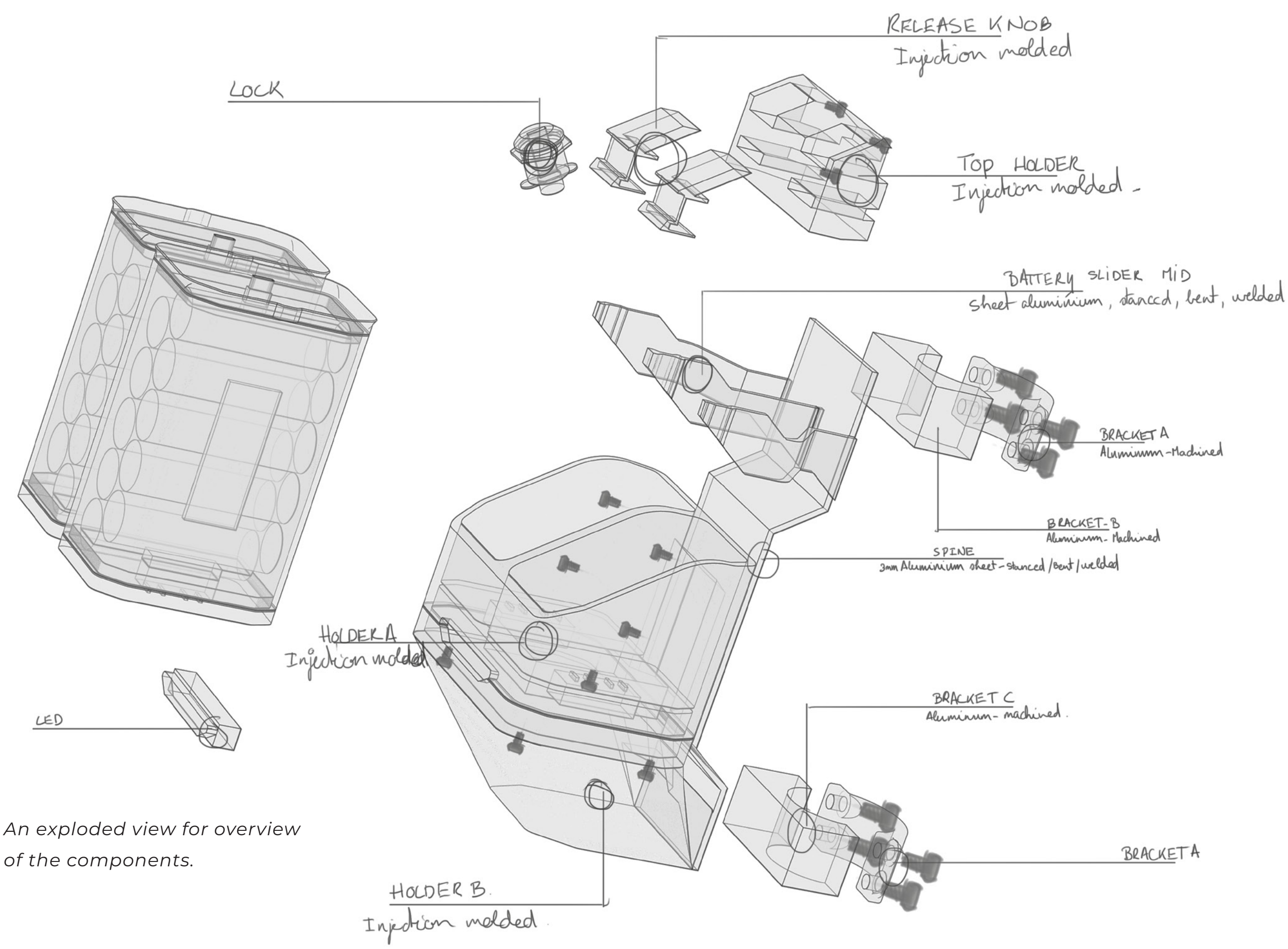


Impression of battery aesthetics

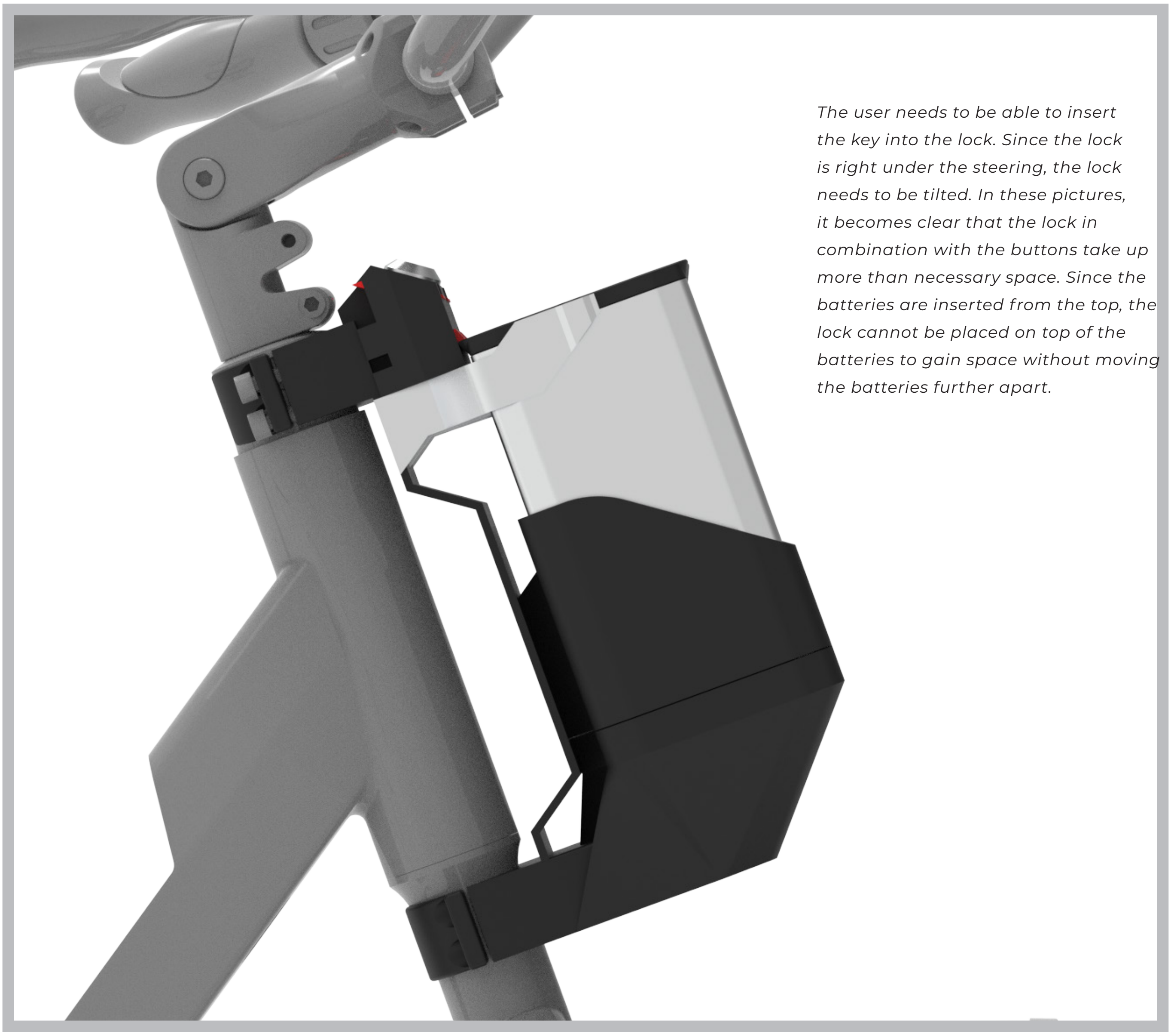
FIRST MATERIAL CONCEPT PROPOSAL

The docking with and without the batteries inserted.

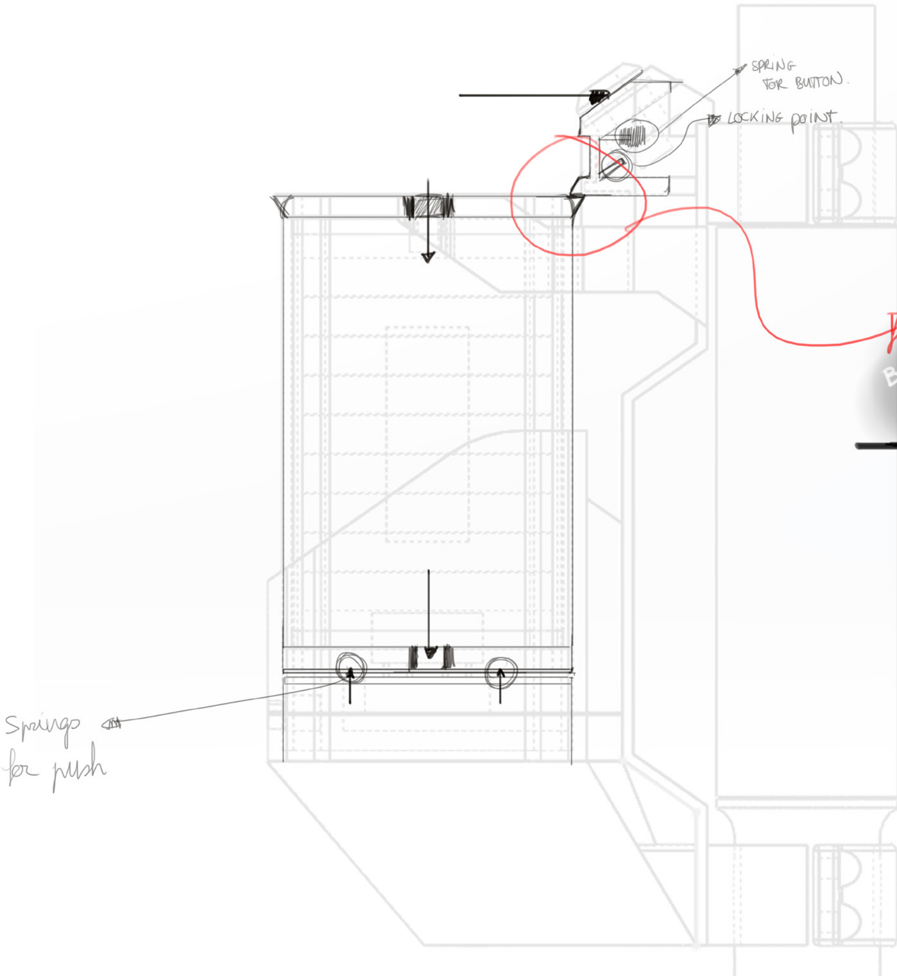


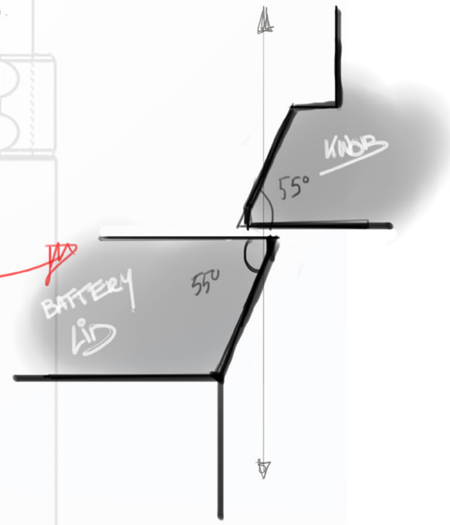


An exploded view for overview of the components.



The user needs to be able to insert the key into the lock. Since the lock is right under the steering, the lock needs to be tilted. In these pictures, it becomes clear that the lock in combination with the buttons take up more than necessary space. Since the batteries are inserted from the top, the lock cannot be placed on top of the batteries to gain space without moving the batteries further apart.





This schematic shows how the battery would be held in place by the knob. The button rests on top of the lid once the battery is inserted. The overlapping material is quite thin. It is probable that the batteries are not held securely when the lid starts to deform and wear due to the use of the product.

Evaluation first design proposal

A lock and two separate buttons are way too voluminous. Due to the sliding through the top, the top part of the battery should stay clear. The lock takes up too much space and increases the distance between the battery holder and headset. The angle in the sheet aluminium weakens the structure.
The brim around the battery at the bottom is too high and massive, and should be smaller. The blades used a the top to guide the battery down are too vulnerable and look strange once the batteries are removed. The battery connection is over-engineered and can be reduced in size drastically. The overall shape of the docking is too cubic, rounded shapes could help make the product appear less bulky.

RESULTING SELECTION CRITERIA

As mentioned at the start of this chapter, evaluation criteria are necessary to go from one stage of the fish-trap model towards the next. Thanks to these first design proposals, we are now able to formulate design criteria based on which the selection can be made.

Vulnerability

The product should stick out at least as possible to the sides of the bike, the batteries must be protected by the structure for impacts. The components and placement should favour a tough design and eliminate vulnerable parts.

Tightness

The design should remain as close as possible around the headset. This is on the hand for the vulnerability of the concept but also as seen in design proposal 1, for aesthetic reasons; the further the docking is away from the headset, the bigger seems the total design. To reduce the total volume of the product, it should remain as tight as possible around the headset.

Lightness

As seen in this first design proposal as well as in the ideation drawings, volumes are add here and there to close of gaps in the structure and make the product seem as a whole. It is now concluded that this is not in favour for perceived volume of the product. A good comparison is the difference between in aesthetics between a car and a bike: the car is a single closed shape whereas a bike is open space-frame.

Simplicity

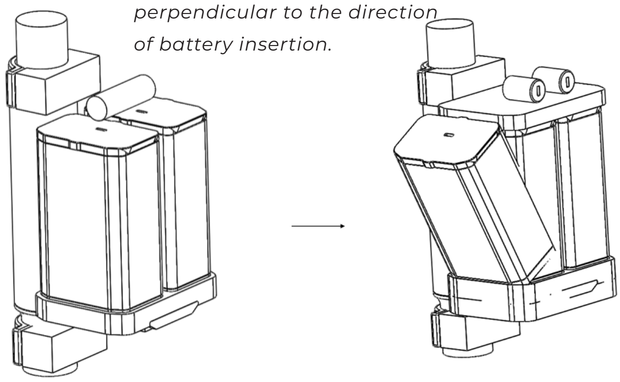
The possibility of releasing the battery without the necessity of turning the keys is the perfect example of added complexity for little added value. The amount of components should be taken down as much as possible, as well as the required user interactions during use.
In a later stage of the morphological study, simplicity of production and assembly is evaluated to progress between the iterations.

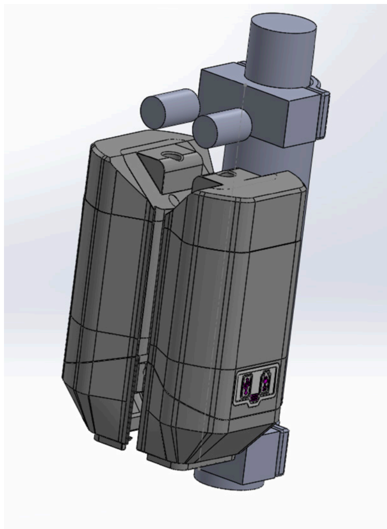
MAJOR CHANGES IN FORMAL CONCEPT

The battery should be placed closer to the headset. the hexagonal shape of stack #0 makes it possible to place the batteries closer to the headset. If stack #0 is used, it also makes it possible to reuse the extrusion profile used to make the battery of Bayck1.
The batteries are inserted from the sides (tilt and click) and the lock(s) can now we placed on the top.
The battery can be released with only the twist of the lock, the buttons are removed.
The brim at the base of the battery is removed, the battery is held in place at the top by the lock and a cover. It is held in place at the bottom by the 5-pin connector and a structural element which rests in the bottom battery cover.

It is questioned if it would be possible to release both batteries at once with a single lock. A functional prototype will be made to test the mechanism.

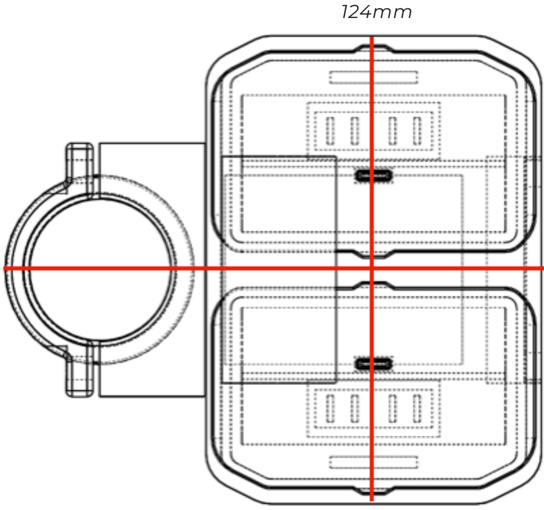
The direction of the lock cylinder needs to be perpendicular to the direction of battery insertion.

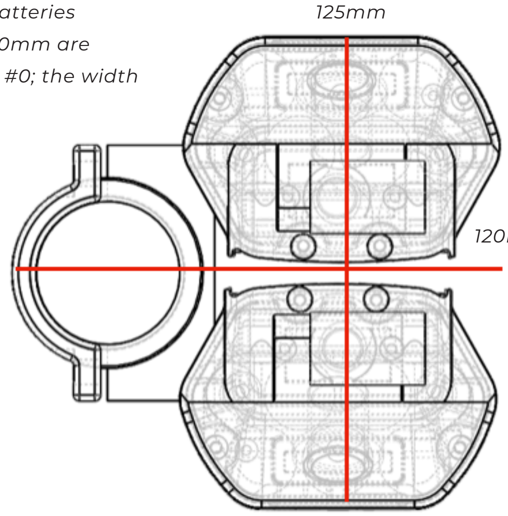




What if we could remove one lock and action both pins with a single one?

The hexagonal shapes makes it possible to wrap the batteries around the headset. 20mm are gained by using Stack #0; the width remains the same.





SECOND PROPOSAL FORMAL CONCEPT

The 2 batteries are built from stack #0.

The batteries are placed in front of the headset, tilted parallel to the headset.

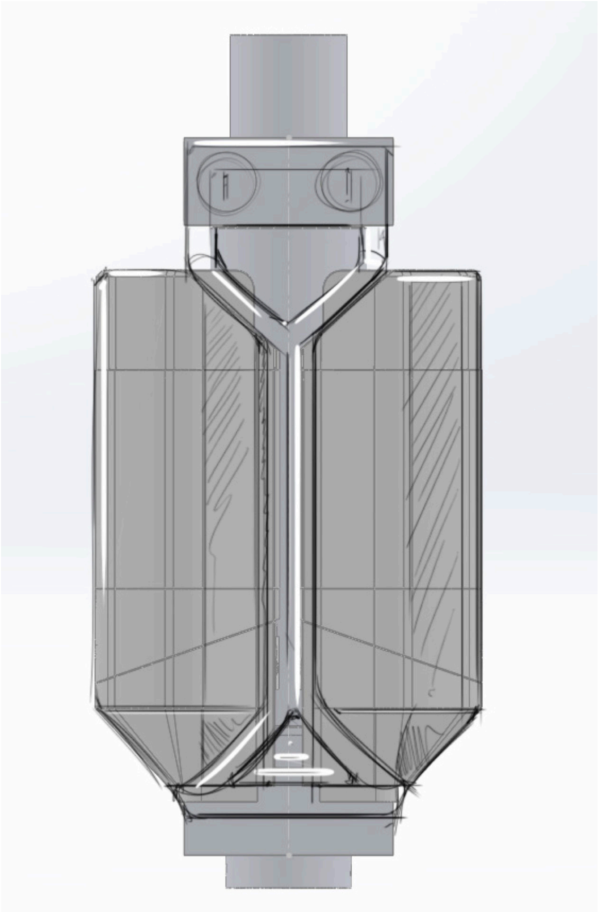
The batteries are placed in the docking with the tilt and click technique.

The battery is held in place at the top by the lock and at the bottom by the connector and blind structural element

The batteries are released by a single lock rotation.

The docking is attached to the frame at the top and bottom with Bayck brackets.

The docking is fixated to a structural rod (called the rack from this point on), which is mounted to both brackets for stiffness.



A first ideation sketch of a possible material concept.

Cell stack

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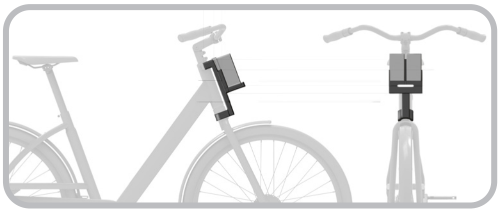

Battery position

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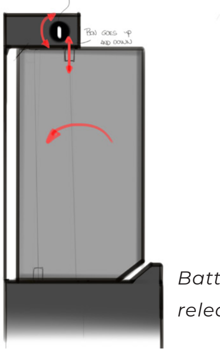

Battery fixation and release

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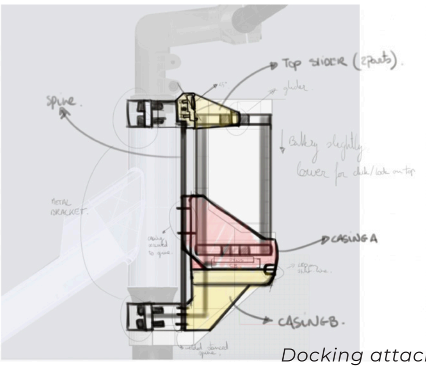

Docking attachment to frame

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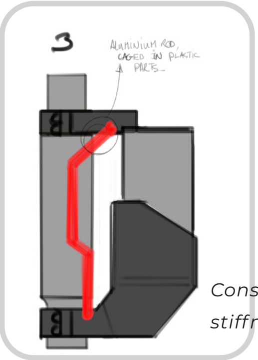


Construction for stiffness.

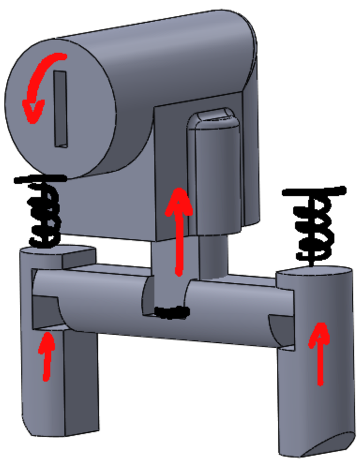
FROM TWO LOCKS DOWN TO ONE

On the right, you see the lock that is currently used in Bayck1. The rotation of the key makes the pin go up, a spring pushed the pin back down. The mechanism inside is made in such a way that the pin can be pushed up without the key-cylinder rotating.

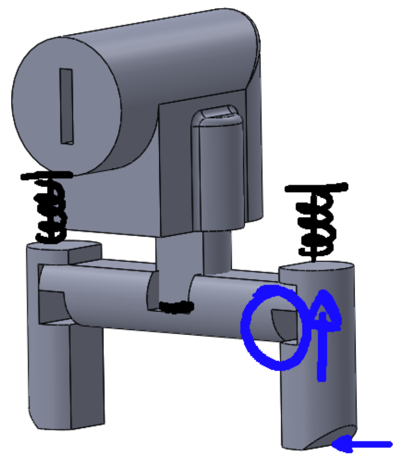
This is crucial feature that should be incorporated in the lock with 2 pins as well: the user should be able to insert the batteries separately without ejecting the other one.

A transmission mechanism is designed to release both batteries at once, but insert-able one at the time.

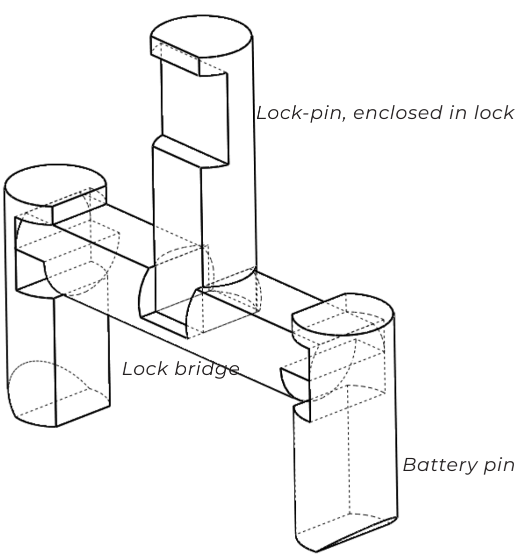
Due to the clearance



With a twist of the key, both pins are lifted up to release the batteries. Due to the spring inside the lock plus the springs above the battery pins, the system is always pushed down to its resting position.



Due to the clearance between the bridge and the battery pins, the pins can be pushed up individually without actioning the rest.
The bottom of the pins are chamfered to translate the lateral motion into an upward motion.



The new pieces for this mechanism are made out of the same piece of 10mm aluminium rod as the initial pin for ease of manufacturing.

The mechanism is machined at the faculty and tested in a physical prototype.

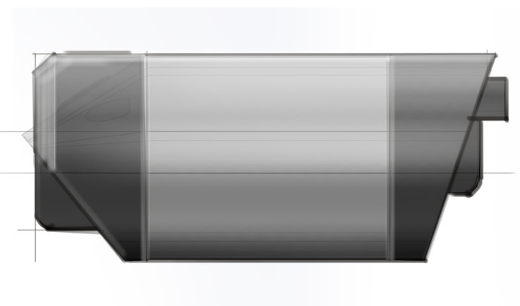
MODIFIED BATTERY CAPS

The battery caps of Bayck 1 are designed in way so they blend in the shape of the frame when they are inserted. The end caps are therefore under an angle, which makes it impossible to let a battery stand on its own.

Once again, since the battery is also a stand alone product, it is preferable that the battery could stand on a table.
The shape of the caps are therefore modified to fit this use.

The top cap is modified as well, to create a little more room on the inside to fit the components.

This is what the batteries look like with a shortened extrusion profile. The ribs on the belly of the battery are there to assure the battery stays straight on the frame of Bayck1, and reduces vibration. The ribs become obsolete on in the new design and could be removed. It also improves the overall visual unity of the battery.



On this first cap redesign, the top cap is modified.
The angled bottom cap with the connectors and structural elements need be modified.

This is a first impression of what a battery could like standing on a table. The ribs are removed from the extrusion profile as well as the caps; the shape of the caps is extended.
The edge of the bottom lid which is facing towards the other battery needs to be other an angle, otherwise the battery cannot be inserted.

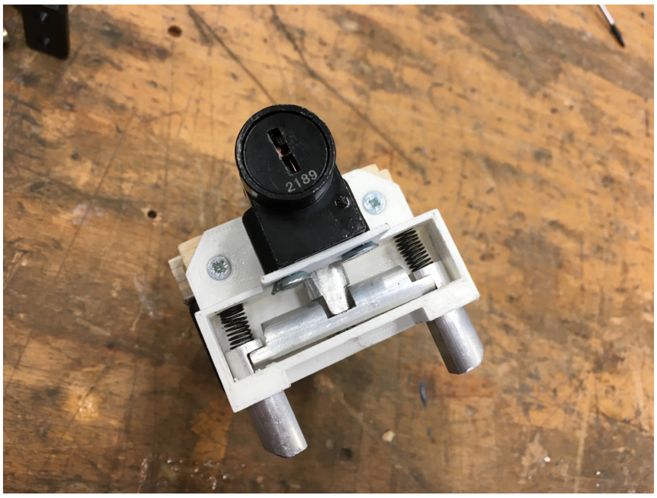
The insertion of the batteries into the lock is tested in a functional prototype.

FUNCTIONAL PROTOTYPE

LOCK MECHANISM

The pins are machined and a plastic casing is 3D-printed to hold the whole thing in place. The twisting of the key should still be comfortable for the user, yet the springs should have enough push to click into their holders on top of the battery; custom springs are turned and fine-tuned until the force feels right.

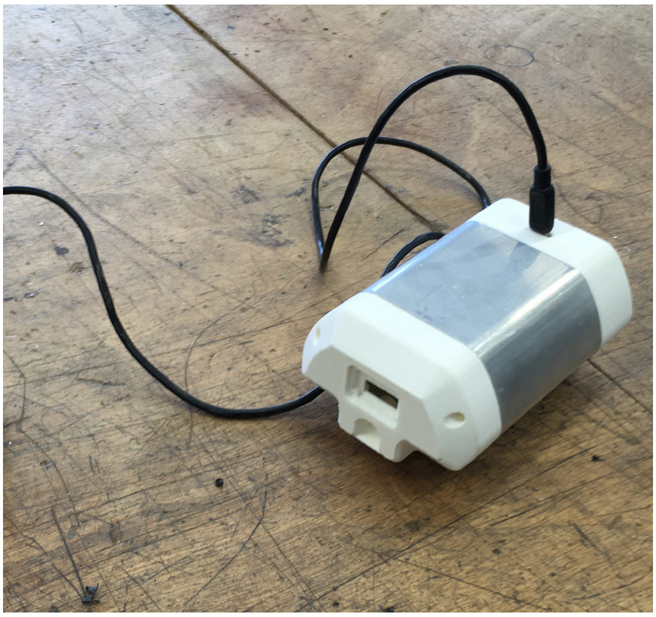
The lock mechanism is mounted on a system which can be easily moved up or down to match the height of the battery. In as second step, the new battery casings and bottom holder must be added.

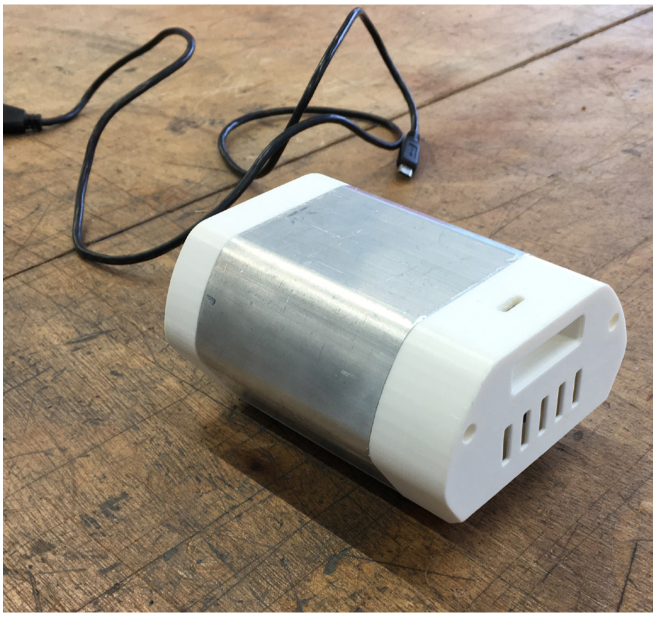


NEW BATTERY CAPS, MODIFIED EXTRUSION PROFILE

On the left, the rib is removed from the extrusion. Luckily, the side on which the rib is placed is nearly flat which makes the operation rather simple.

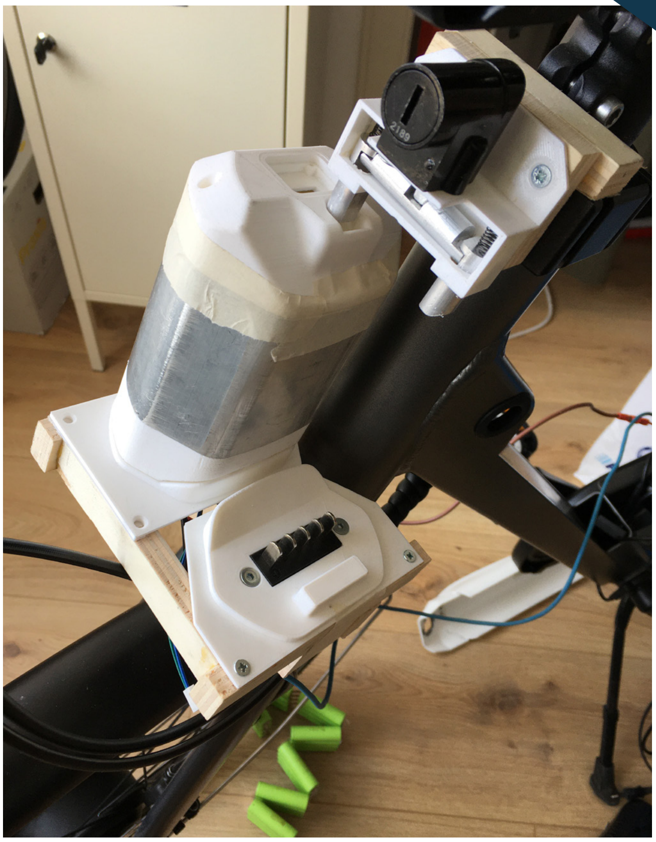
Below, we see the first finished battery casing.





TESTING

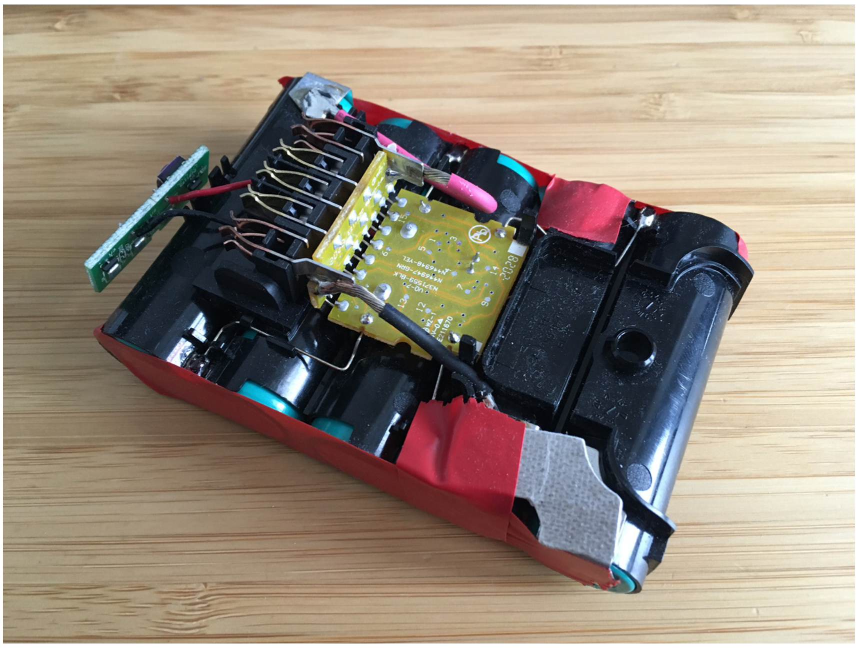
Place-holders for connectors are added on the bottom.
In order to make the model operational, two 18V 2Ah DeWalt batteries are cannibalized; the casings are taken off and new connectors are soldered to the positive and negative pole.
The whole system is then mounted to the front of a Bayck for testing.



PROTOTYPE EVALUATION

The results of this prototype are very satisfactory overall.
The locking mechanism works very well; both batteries are released at the same but do not faal out of the docking, the connectors at the bottom and structural holder keeps them in place. The user actively needs to pull out the battery while twisting the key, which was the desired effect.
The batteries can be placed in individually without releasing the other.
It is momentarily possible to lift up the battery when it is on the docking, which should not be possible; As it was the case on Bayck1, a cap will be added on the bottom of the lock against which the battery can rest to avoid inward or upward motion.
The friction between the cap and the battery pin is quite high, the aluminium strip that was used on Bayck 1 needs be used here as well.

The motor turns on when the second battery is placed and shuts down as soon as it is removed.



The DeWalt battery which is inserted inside the battery casing for testing.

ITERATION STEPS TO FINAL DESIGN

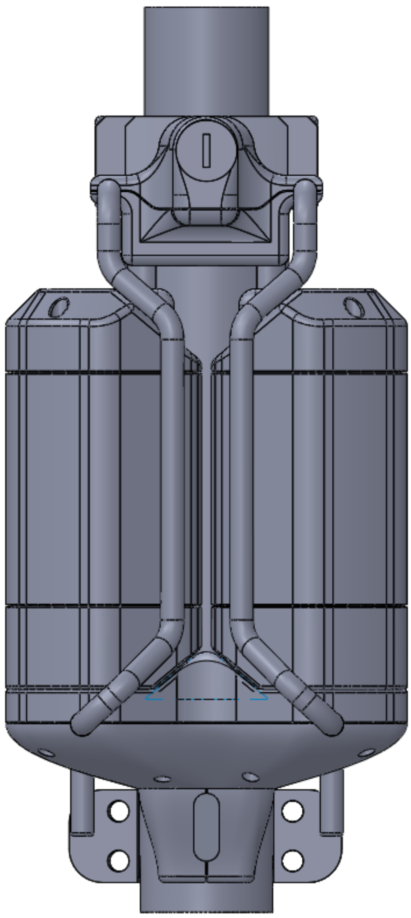
At the satisfactory Green-light meeting, The following digital model is presented. This model mostly shows the intended aesthetics and the placing of the different bodies.
At this point, the exact position of the lock, batteries and other components is completely defined.
Two main design challenges compose the last step of the materialisation:
The shape and fixation of the rack;
The shape, assembly and fixation of the plastic casings.

Different iterations are made and evaluated. The goal is to find a set-up that is simple to produce and assemble with limited new parts to produce to limit extra costs. The final design should compel with the Program of Requirements established in the concept definition.

First visual impressions of the final design presented at the final Green-light meeting.

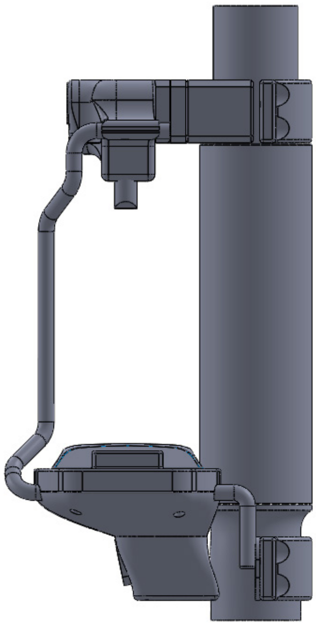
FIRST ITERATION

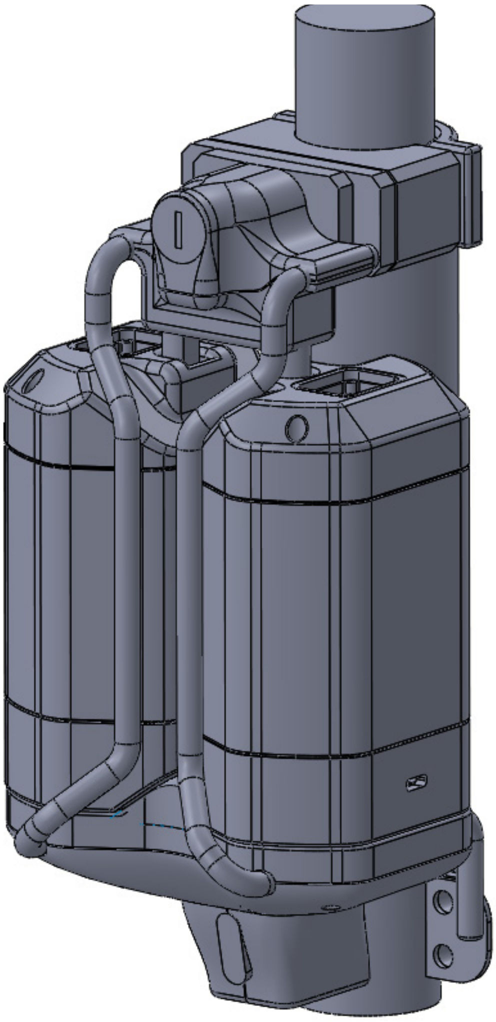
In this iteration, the casings around the lock and connectors at the bottom clamp around the rack for assembly. Since the rack needs to run flat through the casings at the split line, the shape of the rack needs the be modified.
The batteries are held in place by the rack itself instead of a plastic casing, which reduces the amount of needed parts.
The current Bayck interface is used in this iteration as a fixation point for the rack at the top.
The rack is welded to two separate flanges at the bottom which are bolted to the bracket.
On the bottom of the docking, a smaller body holds the LED lamp and functions as a channel for the control-box-to-motor cable to pass through. At the point where the casing touches the form, the cable pierces through the fork.



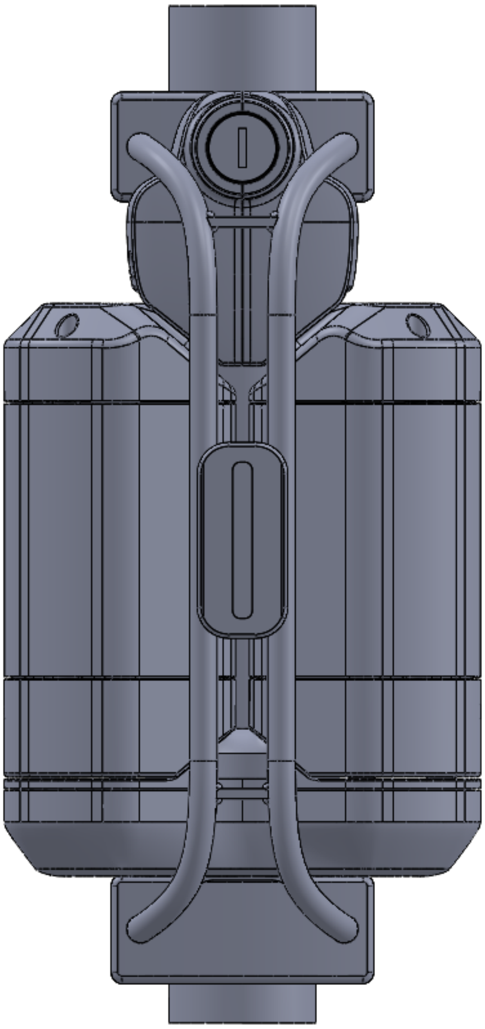
Evaluation:

First of all, the shape of the rack becomes too complex, it fulfils too much functions at once.
The plastic casing around the lock at the top will be extended to hold the batteries in place.
The Bayck interface takes up considerable space; although this construction is favourable for a simple assembly, it has little visual unity. The interface is modified in the next iteration.
At the point where the rack runs in to the casings, it will be difficult to make it watertight, therefore, the rack will run on the outside of the casings in the next iteration.





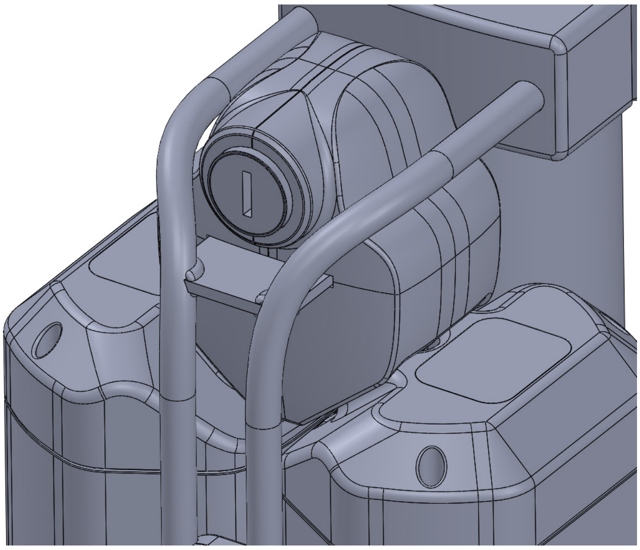
SECOND ITERATION

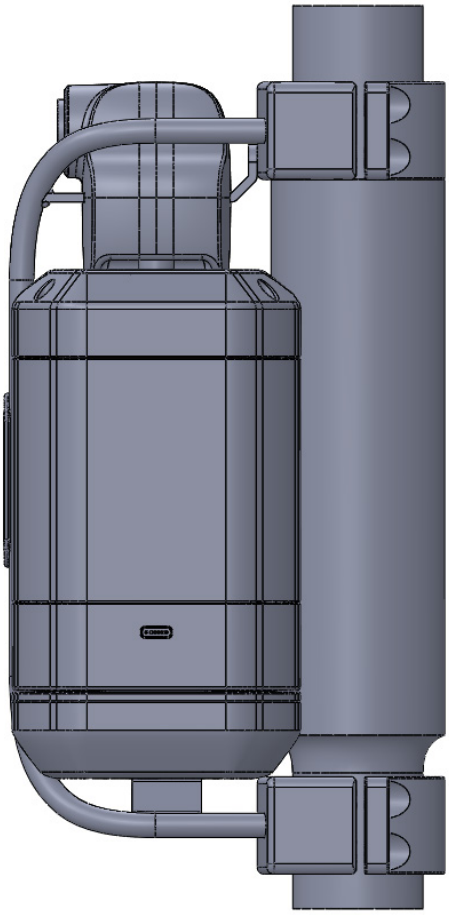


In this iteration, the shape of the rack is simplified; it is now symmetrical left and right but also top and bottom for more visual unity. The interface is shortened and has no two holes in which the rack is inserted and bolted. The interface is the same at the top and bottom.
The rack runs around the casings; The lock is mounted unto an aluminium plate, which is welded unto the rack and rests against the modified interface. The bottom casing of the connectors is bolted to a plate as well, from below.
The casing of the lock is extended and holds the batteries in place.
The body at the bottom is removed, the lamp now clamps around the rack in the front, which ads some stiffness to the structure. The cable does not pierce through the fork anymore, It is concluded that it would make the production and assembly much more complicated.
In this iteration, the lamp runs on its own batteries and is not connected to the control box.

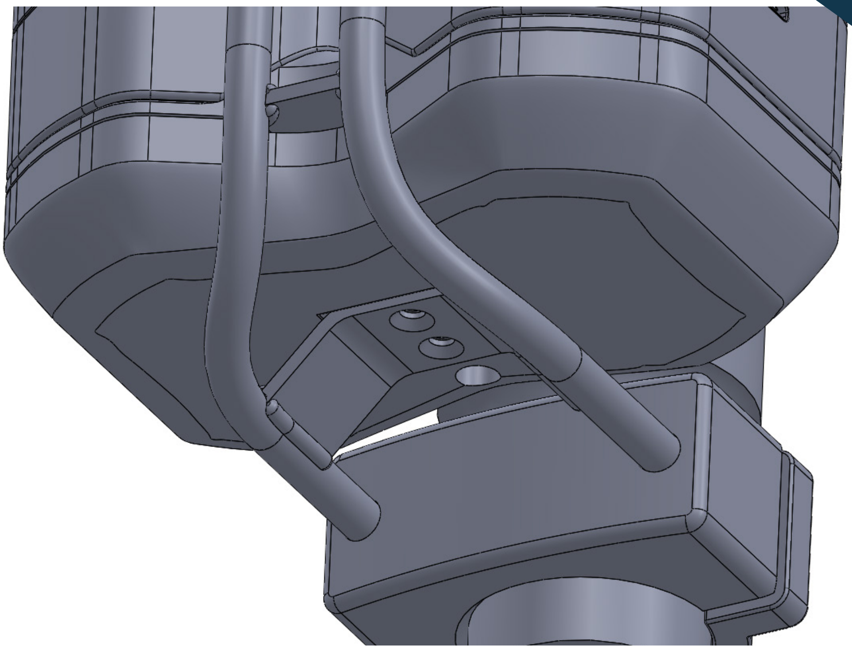
Evaluation:

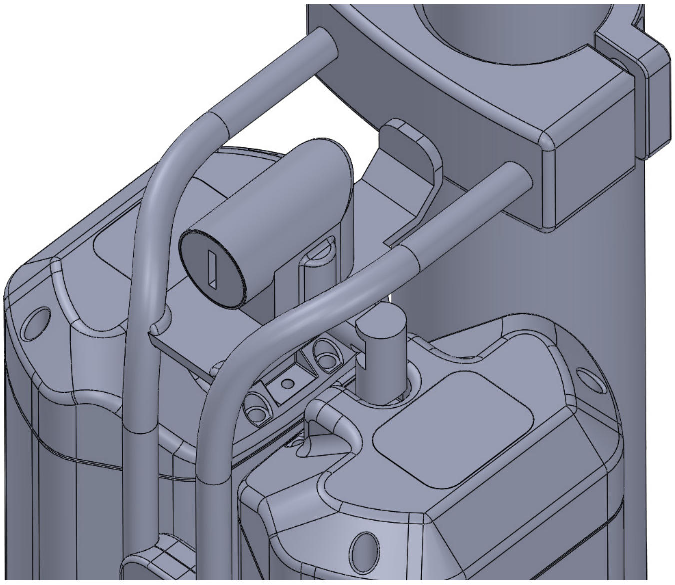
It is a shame that the lamp is running on its own batteries, in the next iteration, it will be bigger and connected to the control box again.
The weld connection between the aluminium plates and rack are quite small and probably too fragile;
It is not clear how the casing around the lock can be assembled in this model, unless the rack is not welded to the interface, but bolted. Drilling and tapering a bent rod is not a recommended production technique.
In the next iteration, The lock casing and connector casing need to be designed in such a way they can be assembled completely as sub-assemblies, sealed and then mounted to the rack in a final assembly step.





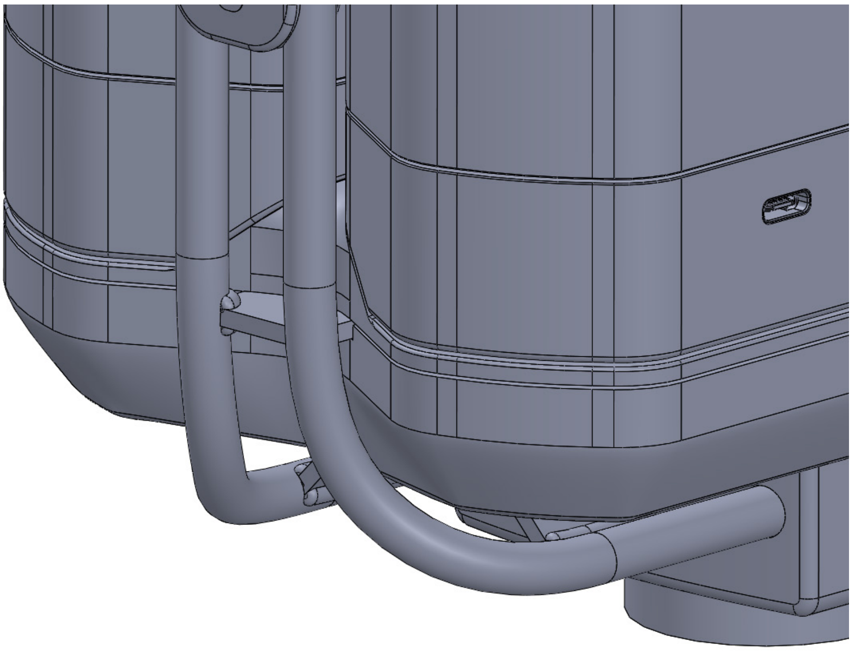
Blind screw holes need to be added at the bottom of the casing to bolt the flange unto the bottom casing. A hole is made for the control-box-to-motor cable in the bottom of the casing.





The lock is mounted on a plate, welded to the rack.
The plate rests against the interface.
The casing clamps around the plate from top and bottom. Is there enough room for the casing to be placed?

At the bottom, the plate comes into the casing as well at the split line between flange and casing. The casing is bolted to the rack at the bottom as well.
The plate may be obsolete and just makes it harder to seal the electronics.



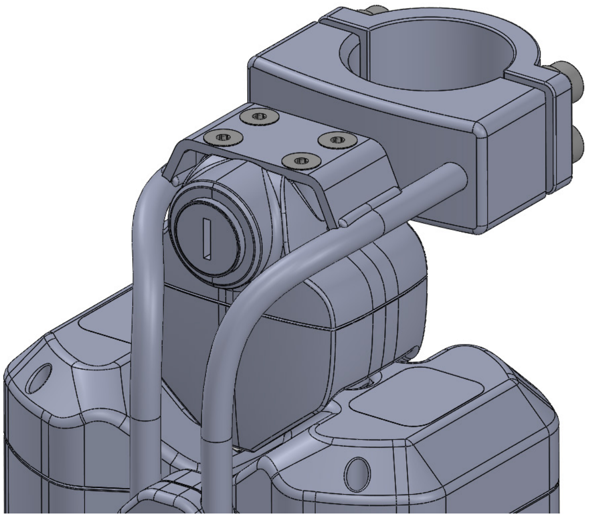
FINAL ITERATION

In this final iteration, The rack remained the same, although the plates are now bigger and tougher; the rack is inserted into the interfaces and welded.

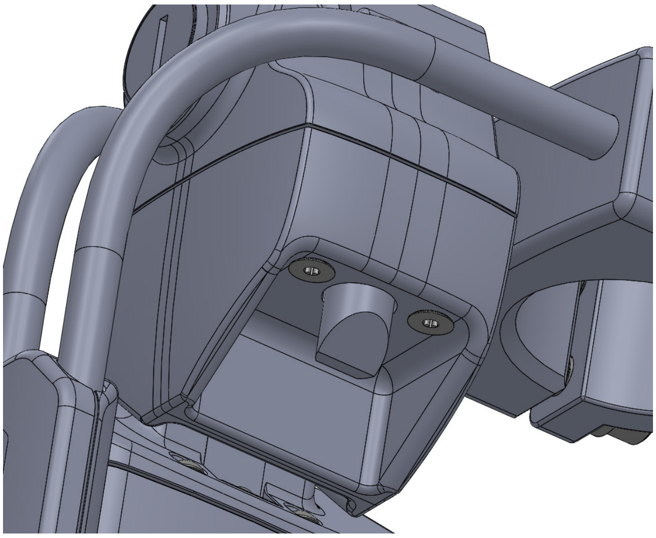
The lock casing and connector casing can now be assembled and sealed before hand, and bolted to the rack to finalize the assembly.
The split line of the lock casing is now horizontal, it makes it easier to insert the lock pins together with the springs and trap them inside the lower part of the casing. The top part of the casing is added as a last step in the lock sub-assembly to seal of the lock casing.

The lamp is made bigger for visual reasons;
The lamp is wired to the control box, the wire comes in the connector casing at the split line.

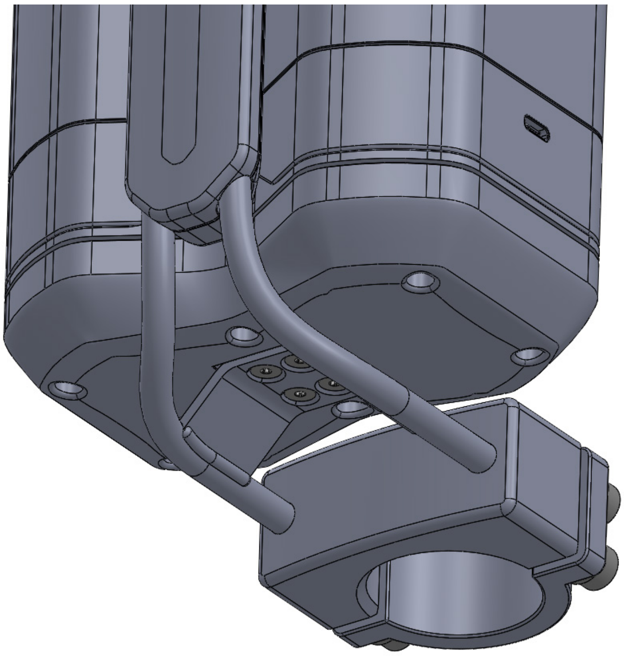
Blind screw holes are add to the bottom of the connector casing



The lock casing is now fastened from above.



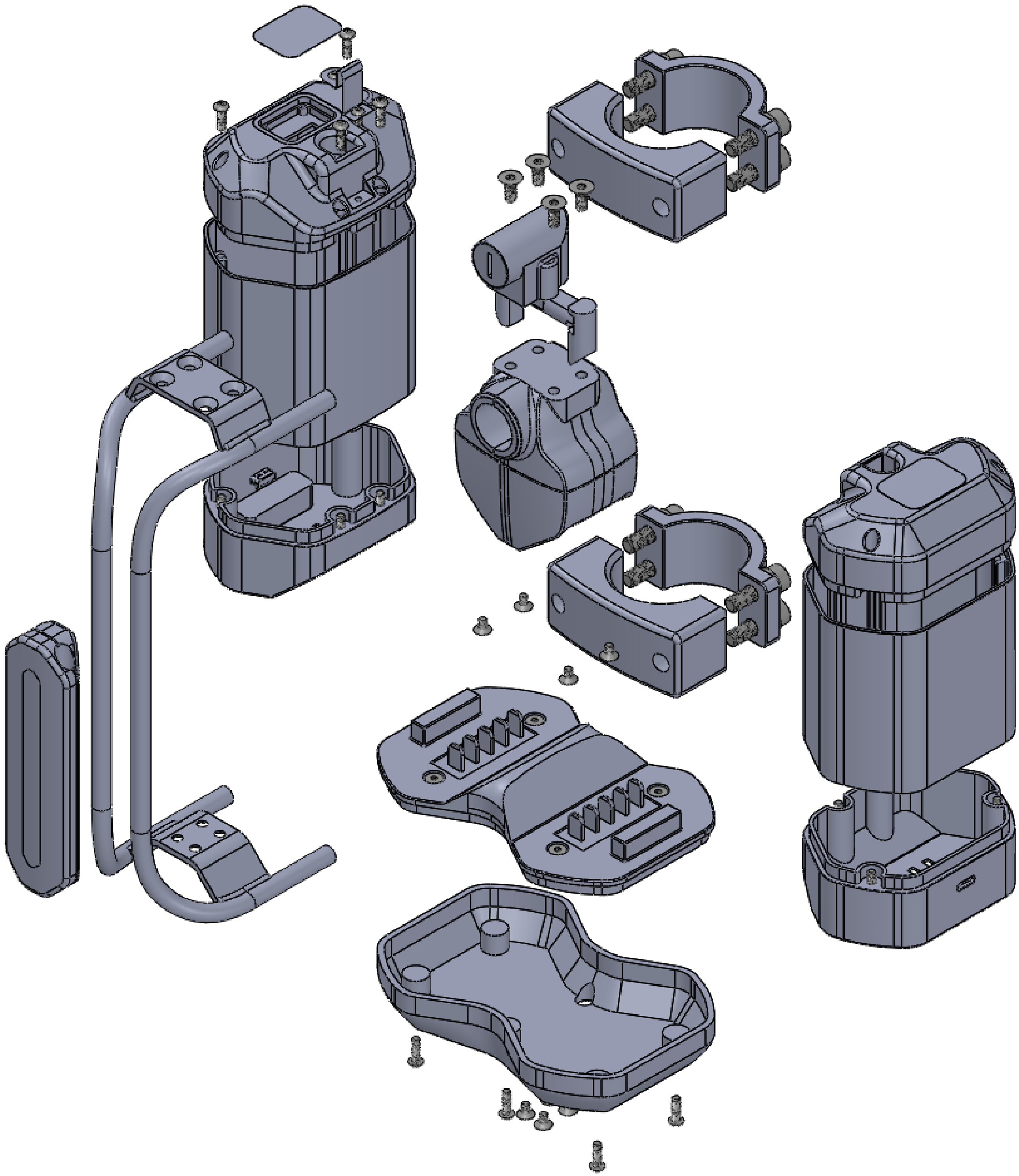
The split line between the two parts of the lock casing is now horizontal. Screw holes are add on the bottom.



Blind screw holes are add to the bottom of the connector casing.

EXPLODED VIEW & ROUGH COSTS ESTIMATION

An exploded view is made to have a better overview of all the final resulting parts. The Bill Of Materials is shared with the client and is asked to make a rough price estimation based on the production of Bayck 1.
Because of the confidentiality of the information concerning production prices and retail prices, only the retail prices will be shared in this report.
The retail price of the basic Bayck1 is 1199.-
As the bike on itself is simplified (removing disc-brakes and gears, reducing machining steps), the production of the new bike is cheaper.
The batteries are less expensive as well, as the amount of cells is reduced. The added amount of casing parts or new connectors do not influence the price considerably.
The final retail price of the new product is estimated at 999.- by the client.



FINAL RENDERS

The final iteration is rendered on a Bayck, together with the wireless PAS.
The right materials are attributed to the parts to evaluate how to product would look like as a finished product. Multiple colour variations are tested for the plastic casings and battery extrusion. The rack and interfaces receive the same finishing as the bracket and initial interface: black powder-coat.

ADJOURNING

CONCLUSIONS

EVALUATION OF THE PROJECT

Gained insights on what an e-bike could be.

It is established that this concept is fundamentally different than the current Bayck design (or other similar e-bikes). The differences and advantages are as follows.

Price-wise, the new concept is indeed cheaper, but that is not the actual point: since the electronics which transforms the bike into an e-bike are not integrated in the bike, the “E-” can be sold individually and could be mounted on any bike. This means you could transform a bike into an e-bike for about €300, which makes the transition to micro-mobility very appealing.

This concept shows that by separating the long lasting components from the components prone to failure or obsolescence, the product can be kept for longer and updated over time. In that sense, this project is a showcase for a new type of business model: a mixture between ownership and lease. The user is invited to invest more time and effort on the long lasting parts (such as frame, battery casings, docking) and update the parts that will fail earlier. The user is owner of the parts for which he has personal affection, and leases the parts that are more vulnerable. With this in mind, it becomes much easier to retrieve damaged electronics for recycling.

This concept opens a new window on the e-bike market. You are not required to be a bike manufacturer to become a player on the e-bike market. This concept proves that it is possible to design a system that can be placed on any bicycle without involving the bike.

The concept also shows a counter-trend to the current e-bike market; the power of the design is within its simplicity and transparency, on the opposite side of highly sophisticated / high-tech e-bikes.

RECOMMENDATION FOR BAYCK

The last phase of the project mostly focused on making a realistic digital model including functional prototypes. This was mainly done because of the learning objectives set at the start of this project. Basically, the materialisation part is maybe less interesting for the company.
At this point in the concept, the actual casings and screw-holes are not relevant.

For the ongoing of the project, I would focus on the combination of the electrical connection and physical connection. As for now, Bayck uses a unique system that can hold only bayck batteries. This is actually valid for all other bike manufacturers out there:
Every E-bike brand has its own interface, which is absurd.
If we look at Professional filming gear for example, all camera’s but also lamps and all other random related equipments runs on a singular universal system called V-lock.
Bayck could find out what the most potent mechanism could be to become a standard.

Finally, I advise Bayck to reach out to a company for collaboration which has the capacity to unroll a battery lease system on a large scale, where Bayck would focus on the design and manufacturing of the universal docking.

REFLECTION

Project reflection

First of all, The assignment on its own was very broad and could have been narrowed drastically from the start. The scope of the analysis was wide: it was a bit about mobility, a bit about biking, a bit about habits in the corona pandemic; it scratched the surface of many different topics without ever taking a deep dive. Even though the conclusions of the analysis were original and engaging, they lost their shine in the formulation of the design brief. The design brief was made in a rush and did not capture the essential of the conclusions.
I personally think this is because too much facets were given to the design brief; it should have been RESET or PERSONAL or MULTI-USE; but not all three at the same time. The design was hovering over these three topics, without ever landing on them properly, which is a shame.
The vagueness of the design brief became flagrant in the ideation and should have ringed a bell: the results during ideation between groups was completely different on rarely on point. The ideation participants struggled understanding the problem that needed to be solved, and that translated itself in bland and corny concepts.
Moving on to the concept definition, the evaluation of the Bayck design is valuable for the company. It came to my attention that Bayck 1 is build with the exact same components as many other e-bikes; Is Bayck satisfied that their bike differentiates itself from other bikes only by the plastic covers on the frame? What makes the Bayck design unique? It would be valuable for the company to re-evaluate and understand the components they used, and minimize the design further to stick to their brand vision, or make a clear statement.
At the start of the materialisation, I was on a mission to design something completely new, starting with a blank page and neglected the valuable resources available in the current design; with hindsight, it would have been more practical to take the Bayck as a starting point and iterate from there. Ultimately, the final design re-uses many Bayck elements, which made the final iteration steps easier.
As the graduation project is meant to be a showcase of the student’s skills, a detailed digital model and a render model were made. These models are less valuable for the client, as the concept itself still has many loose ends.
Many time was spent on the modelling of the concepts, the different parts and assembly even though it added little value to the actual concept.
That time could have better spent on the detailing of the concept, use-cases and the implementation.
To conclude, the urge to finish the project and present a finished visual model took its toll on the overall quality of the project. The full potential of the personal battery, or modular e-bike was not explored and results in a shallow project. There is a mismatch between the level of detailing of the finished visual model and the level of concept depth. A few inspirational renders on top of a rock-solid concept is far more valuable that a finished product of a frail concept.

Personal reflection

Before the start of the project, I had a certain estimation of my skill-set as a designer.
As it turned out during the project, the parts where I performed (and enjoyed) the most were not those I expected.
Interviewing people, understanding behaviour on a larger scale is what grasped my intention the most.
I discovered that the design of living environments, public spaces and how they influence human behaviour interest me far more than product detailing.

A final thought about the project.
I perceived the graduation project as the representation of what I personally stand for as a designer and person; I took the project as well as the criticism very personally.
Since the project was performed for a client which was very implicated into the project, a conflict of interests came up many times during the meeting sessions. In the end, concessions within the project were made to make both ends meet. These concessions weakened the concept and created an unexplainable duality within the final result.
I can imagine that in a situation in which a designer is commissioned by a company, the designer should not let his own personal beliefs take the overhand. It is expected from a designer to give impartial advise and, to a certain extend, be at the service of the client.
In the case of this graduation project, I see two options which could have facilitated the project:
Perform the project without the implication of the client; present the results aiming to inspire the client at the end of the project. A result which is completely embodied by the student.
Or, formulate a design brief that leaves little room for personal interpretation, with a clear statement about the interests of the client. In this way, the student is able to detach himself from the project and let the client interfere without conflict.

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